An Evaluation of the Risk and Return of Diversifying into Forestry on a Sheep Farm using the Capital Asset Pricing Model

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by

Stephen J Bennison

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Abstract

An evaluation of the risk and return of diversifying into forestry by an agricultural based portfolio consisting of the assets lamb, mutton and wool was investigated for the period 1976 to 1996 using the capital asset pricing model (CAPM). Beta coefficients were estimated for each of the assets by regressing the returns from the agricultural and forestry price series against those from the New Zealand stockmarket over this period, which provided an estimate of each assets' market (systematic) risk.

The agricultural portfolio's risk and risk adjusted rate of return was estimated with and without the inclusion of forestry by weighting the average of the betas for each of the component assets. This allowed for the formation of the non-market and market risk-return frontiers for agricultural investment, forestry investment, and agricultural investments combined.

The results indicate that with increasing investment in forestry risk is reduced and returns are increased. Investment in forestry only, showed a nominal return of 9.2 percent and market risk of 4.5 percent (as measured by its standard deviation). The market risk (as measured by its standard deviation) and nominal return for the agricultural portfolio was 8.3 percent and 5.8 percent, respectively. The minimum market variance portfolio was calculated and consists of 65 percent forestry, 14 percent lamb, and 10.5 percent for both mutton and wool respectively offering a return of 8 percent and market risk of 0.02 percent (however, there is still non-systematic risk remaining).

The study also found that if farmers were to diversify into non-productive areas of their farms market risk will be reduced and returns increased.

It was concluded that as a decision whether to diversify into forestry or not, diversification will reduce the risk and increase returns for the sheep farmers of New Zealand.

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1. Introduction

1.1 The Problem Rationale

The past decade has seen massive changes in the primary sector. Farmers are on the international market and, as such, fluctuations in foreign prices have impinged directly on the returns of most farmers, especially with increased exposure to the market since 1984 (Evans 1987). Farmers have had to compete with a number of changes in government policies over time but changes have been particularly dramatic since the election of the Labour government in 1984. These changes have impacted on farmers' returns, none more so than sheep farming. (pers. obsv.).

Prior to 1984, agriculture was a highly regulated sector of the New Zealand economy. New Zealand government policies had the major effects of insulating New Zealand agriculture from international market signals, and consistently reducing the international competitiveness of New Zealand farmers (Dalziel and Lattimore 1996). In effect the agriculture sector was highly protected.

The first form of agricultural assistance came in the form of quantitative controls, licences and border protection in the 1930s (Evans 1987, Rayner 1990). Over the next forty years agricultural technology combined with increasing agricultural subsidies to producers in developed countries and reduced markets, led to falling world prices (Rayner 1990). In particular, Britain joining the European Community in 1972 resulted in increased assistance to British farmers and reducing returns for New Zealand agricultural exports and therefore the economy as a whole (Rayner 1990, Chamberlain 1996).

In due course, the toll that the protection of the domestic industry had on agriculture was implicitly recognised by the government and various forms of compensation were introduced (Raynor 1990). While assistance had long been provided for agricultural activities in the form of research, extension, market development and marketing boards, it was not until the 1960s that there was significant subsidisation at the farm level (Raynor 1990, Griffith and Grundy 1988). However, from then until 1984 there was a gradual acceleration in production grants and concessionary livestock valuation schemes; the various forms of fertiliser subsidies continued to increase in size; and loans at below market rates became increasingly valuable as market rates increased (Raynor 1990).

The reasons why New Zealand found itself with a highly regulated economy are very complex. Instead of allowing international market prices to force a shift towards diversification, domestic policy became increasingly concerned with sheltering the traditional pastoral industries from volatility of overseas commodity prices on farmer investment decision making. The livestock incentive scheme of 1976 was designed to boost sheep numbers at a time when they were falling because of a decline in sheep price returns and Britain joining the European Community in 1972 (Rayner 1990, Chamberlain 1996). Land development encouragement loans were likewise aimed to increase production, particularly on marginal land (Walker and Bell 1994). Product prices were first maintained by cheap loans to the marketing boards so that they could 'stabilise' price through minimum price schemes (Rayner 1990). These loans were subsequently written off when the schemes were terminated (Chamberlain 1996). On top of these subsidised prices came the Supplementary Minimum Price (SMP) scheme, first introduced in 1978 (Griffith and Grundy 1988, Walker and Bell 1994, Chamberlain 1996). The SMP scheme was introduced to complement the price stabilisation schemes operated by the Meat Producer's Board and the New Zealand Wool Board, and to guarantee prices at a level appropriate for income adequacy and for the encouragement of increased farm production and export earnings. The removal of SMP's affected sheep farmers the most as the great majority of payments went to the sheep industry, especially during 1981/82 – 1983/84 (Griffith and Grundy 1988).

Problems with the implementation of agricultural support were of a chronic nature and, as such caused ongoing inefficiencies without forcing immediate corrective action, which had an increasing impact on the fiscal deficit. In 1984, alone the fiscal cost of these agricultural policies to the government was estimated by the New Zealand Treasury to be $1,087 million or 3.2 percent of the country's Gross Domestic Product (Rayner 1987). At the same time the level of support to New Zealand farmers was equivalent to 30 percent of the total output from New Zealand farming (Walker and Bell 1994). These forms of assistance helped to generate a series of large fiscal deficits, and the growth rate of the official debt became insupportable (Ross 1987).

The election of the Labour Government in 1984 saw the removal of protectionism for agriculture. The government believed that market-driven competition was the best way to achieve economic growth (Dalziel and Lattimore 1996). Therefore, the thrust of agricultural policy was to make farming more efficient. This was based on exposing the sector to international prices for outputs and inputs, including government services.

As a result, agriculture was changed from a highly regulated sector to one where it was subject to fewer interventions than had been the case for some considerable period of time. Fertiliser subsidies, land development encouragement loans, the agricultural investment allowance, the livestock incentive scheme and supplementary minimum prices have been abolished. Other forms of agricultural support have either been removed or greatly reduced. The financial markets have been deregulated and the exchange rate floated.

Because of the increased exposure to international market forces, more agricultural trade reform for farmers is still needed despite the recent GATT[1] obligations to reduce trade distortions in agricultural markets, and boost agricultural trade (Chamberlain 1996, MAF 1997). However, given the large scale of agricultural protectionism in OECD[2] countries, these policy changes represent only modest steps towards trade liberalisation. Another problem facing sheep meat exporters is the European Union's (EU) Common Agricultural Policy (CAP). The EU is New

[1] GATT: General Agreement on Trade and Tariffs.
[2] OECD: Organisation for Economic Co-operation and Development.

Zealand's most important market for sheep meat and is restricted by high tariffs while the subsidised export of CAP - generated surpluses depresses world prices and disadvantages New Zealand's unsubsidised exports to third countries (MAF 1997).

The outcome has made farmers vulnerable to market forces both locally and internationally. As a result farming moved from a relatively high income, protected, low-risk environment, to a low income, unprotected environment in which industry now carries risks. An analysis by the Gouin *et al.* (1994) showed that changes in agricultural policy and the evolution of international market prices have contributed to the deterioration of incomes in the farm sector compared with the rest of the economy. The sheep sector was particularly affected by the abolition of price support in 1986 and by the decrease of farm gate prices that resulted from it. In summary the business of farming has become much more risky, and not surprisingly, farmers are now placing greater emphasis on the management of risk.

Farmers face production risk, from the weather, crop or livestock performance, and pests and diseases, as well as government-controlled institutional risk, and personal or human risk. Together with price of market risks, these constitute business risk which is further amplified by financial risk (Hardaker, Huirne and Anderson 1997). All of these factors must be managed to achieve satisfactory returns in farming.

Various management strategies can be adopted to reduce exposure to both business and financial risks associated with sheep farming. Responses may be of a production, marketing or financial nature (Hardaker, Huirne and Anderson 1997).

Farmers may select more stable enterprises, or diversify their operations by combining enterprises which are not perfectly correlated.

Changes in production management could help reduce the exposure to risk. Sheep farmers have a number of options on what they can produce and how they produce it. Gross income can come from: wool sales, lamb sales, mutton sales, and store sheep sales. Sheep income could be influenced producing fine wool or coarse wool, heavy lambs or light lambs, or store stock. The quality and quantity of each can be influenced by management practices such as sheep breeds, stocking rates, and selling practices. Inputs such as fertiliser, animal health remedies, and weed and pest control can also affect the quality and quantity of outputs produced and therefore profits. So instead of simply trying to maximise output, farmers now have the option of producing fewer, better quality products to meet consumer demands (not what farmers were best at producing) (Walker and Bell 1984).

Akin to improved production is better marketing of farm outputs. Farmers can achieve this through access to accurate market information. However, the power of intervention by the marketing boards has been maintained despite the large deregulation undertaken in the whole economy (Gouin *et al.* 1994). As a result, there is the prevailing feeling amongst farmers that the meat industry that represents and markets their products is not doing its job (MAF 1996). The problem faced by farmers is that the meat industry has been production driven rather than market driven (Gouin *et al.* 1994, MAF 1996), although now there is a draft in place for a unified research and development strategy which has the objective to be more market and quality driven (MAF 1996).

Minimising risk from price fluctuations could be reduced by better inventory management, by forward pricing, and spreading sales over time. Mulligan (1997) suggested that forward contracting is an option for beef farmers to guarantee them processing space in the future by aiming to make meat processor preferential-supplier lists. Contracts also encourage farmers to consistently supply quality meat over a period of time, which is negotiated with a particular meat processing company. This prevents oversupply and allows the farmer to spread risk and returns. The same could also apply with sheep meat products, however, the sheep sector has been slow to adopt a strategy and the sector also needs to have complete confidence in the processor (Christchurch Press 1996, MAF 1996).

Changes in financial management may also provide protection from business risk; more liquid assets may be held, insurance can be taken out against various contingencies, fixed-term payments may be restructured so that the annual drain on cash reserves falls, and assets can be leased rather than owned (Brigham and Gapenski 1991). Financial risk may be reduced by adopting various risk management practices through diversification of farming operations, by adding alternative ventures such as deer, horticulture, forestry and goats to farmers base operation (Chamberlain 1996), or by off-farm investment[3].

[3] An option for off-farm investment could include investment in forestry in other more productive parts of the country, for example; B Koller, Consultant, Wellington (pers. comm.).

Since most agricultural products are exported, the deregulation of the economy combined with a high exchange rate has seen a decline in real returns for sheep farmers and this has increased the uncertainty surrounding their future cashflows (MAF 1996). In the market led economy, the government has said these are market problems, not requiring intervention or change of policy (Christchurch Press 1996). An important feature of this increased uncertainty is that it provides an incentive for diversification. The addition of different products with different risk-return characteristics will typically improve the combinations of risk and return the farmer can achieve (Evans 1987). As a consequence, efforts to diversify appear to have been intensified by these farmers.

1.2 The Problem Defined

The issue of how to diversify appropriately in the face if risk, or to select an optimal portfolio of activities, has been well researched in the economics literature. However, there appears to be little published research focusing on the risk and return of diversifying into forestry for sheep farmers, despite the fact that more and more farmers are investing in forestry as an option for spreading risk.

Farmers in New Zealand have had to reappraise their land-use decisions because of the liberalisation of the New Zealand economy. Surveys of farmers' attitudes to planting trees in the past have shown that non-economic factors have been important in farmers' decisions to plant trees. Recent literature has shown that economic assessments are important (MAF 1996).

The hallmark of single farming systems is their inability to produce a range of outputs that can buffer one another should prices, climatic or disease have a negative effect on a particular output (Cairns 1992). Thus, in order to survive in a single farming system, farmers must be prepared to manage risks and produce a range of outputs so that some outputs will have a return when others are low. The farming system should be flexible to allow this to happen with sound contingencies in place.

The addition of different products with different risk-return characteristics will typically improve the combinations of risk and return the farmer can achieve. Diversity of income sources can reduce the risk of income fluctuations from a narrow, specialist operation, such as sheep farming.

It is expected that farmers will increase the rate of farm conversion into plantation forestry on the basis of expected good future returns from forestry (Daké and Squire 1993). Diversification into forestry gives farmers the option to offset some of the risks associated with the sheep industry. There are many reasons why farmers should consider forestry as an investment class[4] (Hammond 1995). These include:

- estate planning – how to share this generation's assets with future generations;
- shelter and shade for homes and stock;

- lower risk as the establishment phase is over;
- improving equity in the property;
- increasing farm surplus;
- biological growth which means increasing value and volume;
- some liquidity[5] – through sell back provision to other investors by means of joint ventures and leases, for example, and;
- reduced overall risk negative through correlation with most other asset classes.

There appears to be a shortage of reliable information in New Zealand on forestry investment (Bell 1994), so most experiences have been drawn from the United States.

Forestry offers investors such benefits as protection from inflation (Graham 1985) and portfolio diversification (Mills and Hoover 1982, Conroy and Miles 1987, Mills 1988, Zinkhan 1998). One reason for the existence of the inflation protection and portfolio diversification benefits is a rather unique feature (for an investment alternative) provided by forestry: biological growth (Bell 1994, Zinkhan 1990). Forests continue to grow, resulting both in volume increases and perhaps more valuable merchantability classes, independently of the vagaries of the financial markets and there is no intuitive relationship with the returns of financial assets (Bell 1994, Zinkhan 1990). Furthermore, price changes for forestry and the land base

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[4] B. Bell, Forestry Consultant, Wellington, (pers. comm.).

[5] There are investors who have the perception that liquidity is low with no established market at present for smaller individual stands of immature trees. However, this perception seems to be changing; B. Bell, Nimmo and Bell, Consultants, Wellington, (pers. comm.).

represent potential sources of return which may contribute not only to forestry's diversification potential, but also to its inflation protection potential (Bell 1994).

Researchers in the United States have shown that forestry is included in preferred portfolios when combined with traditional financial investments. A study by Mills (1988) between 1959 and 1978 compared the average annual rates of return, standard deviation of the rates of return, and the correlation coefficients between a 40-acre uneven-aged stand in West Central Indiana on an average site (black oak site index 65) and other investments, including such alternatives as the S&P 500 Composite Index, preferred stocks, Treasury bills and notes, and municipal bonds. The study concluded that this forest investment is negatively correlated with 11 of the 14 investments analysed. It is only strongly correlated with farm real estate and commodity futures. [The results of a study by Daké and Squire (1993) indicated that it was risk efficient for pastoral farmers to plant *Pinus radiata* forest on a portion of the farm.] This is noteworthy because an addition of an investment possessing low or negative correlations with other portfolio assets' returns results in a reduction in the volatility of portfolio returns. Conroy and Miles (1987) reported negative correlations between their southern pine timberland index and a comprehensive stock index, a small common stock index, and a long-term Treasury security index. These researchers did observe a slightly positive correlation with Treasury bills.

Binkly and Washburn (1988) estimated that loblolly pine plantations in South Carolina had mean annual returns as high as 11.1 percent in the period of 1956 to 1984. Such competitive returns in conjunction with low or negative correlations with many financial assets suggest that forestry may be an attractive addition to diversified portfolios.

A preliminary analysis by the New Zealand Forestry Exchange indicates that New Zealand forestry may exhibit the same relationship with the market as in the United States indicating that forestry may be a useful diversifying instrument for investors (Bell 1994).

Finally, in regard to output price volatility (i.e., the volatility of forestry and sheep prices), forestry possesses an important advantage over farmland: forestry sales can generally be deferred if prices are currently perceived to be inadequate, and unlike most other commodities that accumulate with storage, forestry increases in value over time (Zinkhan 1990, Zinkhan *et al.* 1992, Bell 1994). For commercial forestry in the United States researchers found a ten or eleven year window of potential optimal harvest. By selling only when prices are 5 percent above the twelve-month rolling trend line for forestry prices returns are raised and variance lowered (Bell 1994). This unique aspect separates forestry from other asset classes.

Traditionally, foresters tend to think of forest valuation in terms of discounted cash flow analysis that determine the present value of a stand based on a series of finite or infinite cash flows. In agriculture, farmers tend to use gross margin analysis to compare alternative enterprises, forestry included, on a per hectare basis. However, neither of these methods is helpful in comparing relevant risk-return relationships of forest investments vis-à-vis investments in other asset classes.

A planning tool that is available to farmers to assist in their diversification decisions is the Capital Asset Pricing Model (CAPM). Models like the CAPM can be useful by providing a way to judge the riskiness of potential investment opportunities as the CAPM links together the risk and return for all assets (Bilek 1996, Prest and Turvey 1965). This can help managers use the resources of their firms more efficiently (Jagannathan and McGrattan 1995).

Forestry like most other forms of human activity is prone to follow fashions simply because they are fashionable. Unfortunately the performance of fashionable techniques is not as always spectacular as their early promise. It can therefore be useful to attempt an objective evaluation of the potential and the limitations of a new development, no matter how good it looks (Leslie 1967). In view of this, capital budgeting has a central role when making capital expenditure decisions. With capital budgeting there are a number of alternatives when evaluating whether or not to invest in a project (Prest and Turvey 1965). A key input to that process is the cost to the farmer of financing capital expenditures, known more simply as the cost of capital. This is the expected rate of return that the farmer will require for investing in a specific project, for example, forestry. The cost of capital typically depends on the particular project and the risk associated with it. To be able to evaluate projects effectively, it is necessary to assess the risk and determine what risk premium to demand. The CAPM provides an estimate of the relationship between risk and the cost of capital (or the risk premium for investing in the project) (Jagannathan and McGrattan 1995).

Studies have shown that forestry appears to be a good investment, for example, forestry has shown low or negative correlations with most asset classes and this can reduce the overall risk. Also, real returns can be in the order of 9 to 15 percent (Horgan 1996). This sounds attractive but most studies have concentrated on tradable securities such as stocks and bonds when comparing risk and return with forestry.

Investment in forestry is becoming more accepted as an option for farmers, therefore, it would seem timely to investigate the option of diversifying into forestry to see whether this activity can assist New Zealand sheep farmers in determining whether forestry can reduce risk, and improve a farmer's portfolio returns.

1.3 Aims and Objectives

The aim of this report is to evaluate the risk and return of diversifying into forestry on a New Zealand sheep farm, using the Capital Asset Pricing Model (CAPM).

The consequential objectives of the study include are:

- To quantitatively evaluate the impact of diversification into forestry by an agricultural based portfolio.

- To suggest an appropriate mix of forestry in order for a farmer to construct an efficient portfolio.

- To construct a framework to enable a farmer to determine an appropriate mix of forestry in an efficient investment portfolio.

2. Portfolio Theory and the Development of the Capital Asset Pricing Model

2.1 Introduction

In this chapter the fundamental concepts of portfolio theory are introduced. Portfolio theory has been widely reviewed in the literature and therefore this chapter will provide only an overview. Tracing the evolution of modern portfolio theory and its widely used adaptation, the Capital Asset Pricing Model (CAPM), will allow the reader to value the CAPM for evaluating diversification decisions concerning investment in risky prospects, such as a farm management plan to invest in forestry.

The first section of this chapter briefly discusses the notion of decision analysis. Section 2.2 looks at the mean-variance criterion, as the CAPM uses the Markowitz mean-variance framework. Section 2.3 discusses the application of the mean-variance efficiency criterion and portfolio theory. The final section introduces the CAPM.

2.2 Farm Management Approach to Planning in a Risky Environment

2.2.1 Decision analysis

When planning under risk some form of decision analysis is required to meet the objectives of the farmer or farmers[1]. Decision analysis is the name given to the family of methods that have been developed to try to rationalise choice in an uncertain world. Almost all of these methods depend on strong presumptions about how risky decisions can be improved. Depending on the nature of the problem, particularly on how many choice options exist, finding the best choice may be a simple or a more difficult task. In the latter case, methods such as mathematical programming or dynamic simulation may be appropriate, especially when there are very many options to be considered.

In many cases these models require elicitation of the farmer's utility function or preferences. In some instances this is not possible, or, as in the case of this report, the analysis is aimed at a group of farmers numbering perhaps some hundreds or even thousands. Efficiency criteria were devised in an attempt to rank choices without specifying the utility function except in limited-information terms.

[1] Much of this material has be drawn from Coping with Risk in Agriculture, Hardaker *et al.*, 1997.

Efficiency analysis depends on making some assumptions about preferences, i.e., about the nature of the farmer's utility function, thereby avoiding the need to elicit a specific function. Often bounds are placed on the level of risk aversion. There are a number of moment based decision rules, but the one that is most commonly used is the mean variance criterion and its derivation the capital asset pricing model (CAPM).

Efficiency criteria are useful in situations involving a single decision maker whose preferences are not known, in situations involving several decision makers whose preferences yet conform to a specific set of restrictions, and in analysing policy alternatives or extension recommendations that affect many diverse individual. They are also useful in deriving widely applicable theoretical result. As such, efficiency criteria are valuable tools in risk analysis.

2.2.2 Mean Variance Rule and the Minimum Variance Set

A decision rule developed for evaluating risky investment alternatives is the mean-variance rule, or the E-V rule (Markowitz, 1952). The mean variance or E-V efficiency rule is based on the proposition that, if the expected value of choice A is greater than or equal to the expected value of B, and the variance of A is less than or equal to the variance of B by all decision makers whose preferences meet certain conditions. In symbols portfolio *A* is preferred to *B* by the E-V rule if:

$$E(r_A) \geq E(r_B) \text{ and } \sigma_A^2 \leq \sigma_B^2$$

The conditions are that the decision maker always prefers more to less of the measures of consequence x, and is universally not risk preferring with respect to the level of x (Hardaker *et al.* 1997). Additional requirements for the rule to be exact assumes that the decision makers investors are risk averse and asset returns are normally distributed, which implies that the mean and variance provide all relevant information about a risky asset. Although distributions of forecasted returns from assets are not always normal, it is often assumed that that they are in order to simplify analysis decisions (Dobbins and Witt 1983, Harrington 1987, Hardaker *et al.* 1997).

Figure 2.1 illustrates a set of investment opportunities. The investor can select any portfolio on or inside the hyperbola. Using the E-V rule, portfolio K dominates portfolio L because K has a lower standard deviation for a given level of return. Therefore, rational investors will only select portfolios on the minimum-variance set. The *minimum-variance set* is a locus of risk and return combinations that minimises the portfolio standard deviation for a given level of return. For assets that are not perfectly correlated, the curve above the MVP is concave and the part below the MVP is convex.

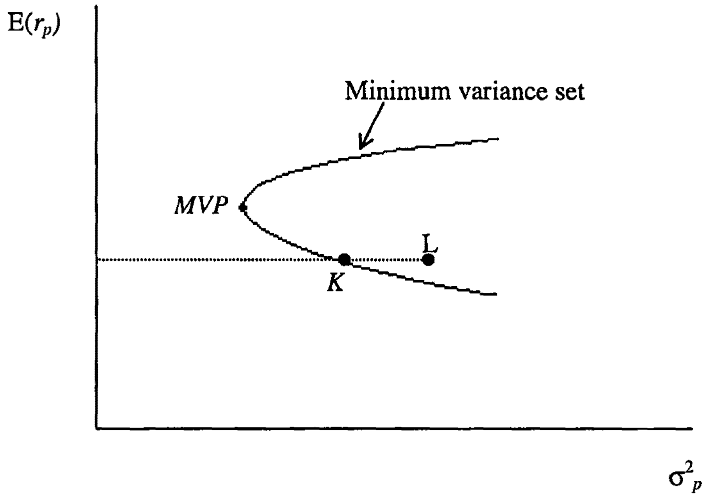

Figure 2.1. The minimum variance set

The minimum-variance set can be divided at the MVP into a top and lower half. The second E-V rule eliminates from consideration portfolios below the MVP. Investors prefer portfolios on the top half, called the *efficient frontier* because the return is greater for a given level of risk. In Figure 2.2 an investor refers portfolio *S* to *T* because *S* has a greater return for the same level of risk. While both portfolios are on the minimum variance set, only *S* meets the criterion for the efficient frontier.

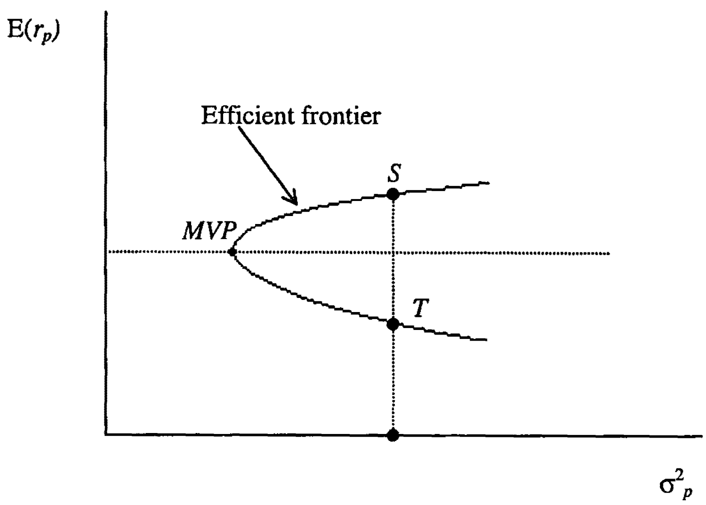

Figure 2.2. The efficient frontier

A rational investor will select an efficient portfolio, which is a portfolio on the efficient frontier. An extremely risk-averse investor will select a portfolio close to or on the MVP, while a more adventurous investor will select a portfolio with greater risk and return.

The selection of an optimal farm plan, through the process of evaluating and determining risky strategy choices along an E-V efficient frontier will lead to a utility maximising point of tangency between the individual's utility function and the E-V frontier. This is illustrated in Figure 2.3.

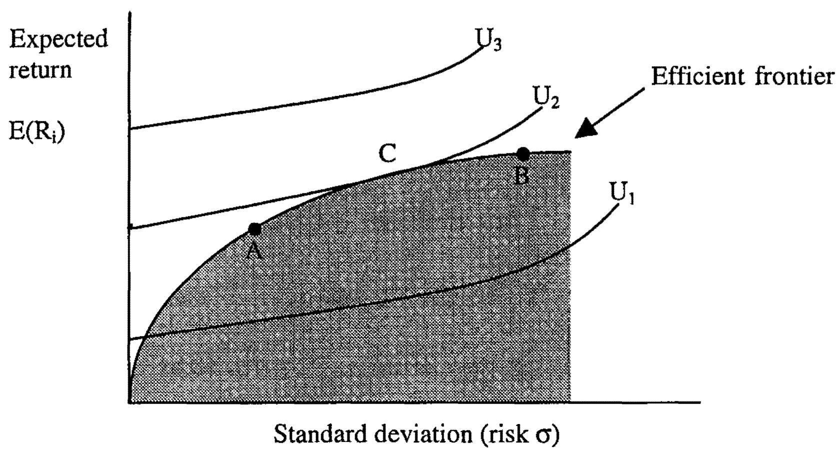

Figure 2.3. The efficient frontier and utility maximising point (C) in a portfolio model

A risk-averse decision maker will have indifference curves with positive gradients such as U_1, U_2 and U_3 (Hardaker *et al.* 1997), as illustrated in Figure 2.3. Successively higher indifference curves represent successively higher levels of utility, since for a given level of risk, expected return increases. If the risk-return trade-off is known, the possibilities offered by combination of risky assets is also known (Dobbins and Witt 1983). Therefore, the optimal mix will be a point on the north-western frontier of the set, such as C (Hardaker *et al.* 1997).

Although an investor has an unlimited number of risky portfolios to choose from, the opportunity set can be substantially reduced by utilising the mean-variance (E-V) decision rule. The minimum variance opportunity set, which is hyperbolic in an expected return–standard deviation for a given level of expected return.

2.3 Portfolio Analysis and the E-V Rule

One common application of the E-V efficiency analysis is to decisions about a mix of risky prospects (Hardaker *et al.* 1997), such as a farm management plan to invest in forestry, and its usefulness provides much of the framework for portfolio theory. Portfolio theory is concerned with the choice of efficient combinations of assets resulting from the benefits of diversification across different assets.

Portfolio theory states that the contribution of two activities the returns of which are not fully correlated will provide a combined volatility that is less than that of either asset. The manager attempts to reduce volatility by seeking activities having a small or negative correlation between returns in the managed portfolio, and tries to reduce volatility without reducing the total return. This theory provides a measure of risk which, is, in theory, both objective and quantifiable; and provides a framework in which risk and return are considered at the same time. It provides a method to construct portfolios which will generate the greatest return for any desired level of risk. It also identifies the most efficient form of diversification.

Portfolio theory uses three pieces of data: the expected return on an activity, the standard deviation of the return and the covariance between returns on different activities (Brealey and Myers 1991). The standard deviation is used as the proxy for risk in portfolio theory, while the covariance is a measure of the extent to which returns on two activities move in the same or opposite directions. That is, the higher the standard deviation of an activity the less stable and so the riskier the return.

The expected return on a portfolio $E(r_{port})$ is the weighted average return of the individual activities in the portfolio, with the weights being the proportion of the total funds invested in each activity (Brealey and Myers 1991). That is:

$$E(r_{port}) = \sum_{i=1}^{n} x_i r_i \qquad (2.1)$$

where $E(r_{port})$ is the expected rate of return on the portfolio, x_i is the fraction of the portfolio invested in asset i, r_i is the expected rate of return for asset i, and n is the number of assets in the portfolio.

The standard deviation of the portfolio, σ_p, is determined by the standard deviation of each activity, the correlation between each pair of activities; and the amount invested in each activity. That is:

$$\sigma_p = \sqrt{\sum_{i=1}^{n} x_i^2 \sigma_i^{\ 2} + \sum_{i=1}^{n} \sum_{\substack{j=1 \\ i \neq j}}^{n} x_i x_j Cov_{ij}} \tag{2.2}$$

where σ_p is the standard deviation of the portfolio, x is the weights of the individual assets in the portfolio, where weight are determined by the proportion of value in the portfolio. σ_i^2 is the variance of asset i, and Cov_{ij} is the covariance between the returns for assets i and j.

Equation 2.2 indicates that the standard deviation for the portfolio is a function of the weighted average of the individual variances, plus the weighted covariances between all the assets in the portfolio. That is, the standard deviation for the portfolio encompasses not only the individual variances, but also the covariances between pairs of assets.

A portfolio is inefficient if either some other portfolio exists which has a higher average return and no greater standard deviation, or alternatively has a lower standard deviation and no lower average return.

The efficient set, which is also known as the efficient frontier consists of all activities and portfolios that lie on the curve and indicates the minimum variance of returns for given levels of expected returns.

Movement along the efficient frontier reflects a trade-off between the expected returns and the variance of those returns. The selection of a portfolio by the investor on this efficient frontier is defined by that individual's utility function and degree of risk aversion. This is illustrated in Figure 2.3, where a farmer who selects a portfolio (or a farm plan) at point B is exhibiting a higher degree of risk aversion, than a farmer who selects at point D, since the farmer who selects B is opting for a lower level of risk and expected returns than the farmer who selects at point D. For an individual farmer, therefore, the optimum of the risk efficient farm plan, is the point of tangency between the efficient frontier and the E-V utility curves.

Farm planning models to find the appropriate degree of enterprise diversification have conventionally been cast in the E-V, or portfolio selection framework. The means and variances are easy to work with, and not surprisingly, a lot of theoretical work in decision analysis uses the E-V criterion (Hardaker *et al.* 1997).

2.4 A Technique for Farm Planning that Incorporates Risk: The Single Index Model

In order to identify the efficient set of portfolios in the Markowitz model, a huge quantity of data is required. In particular, it is necessary to know the covariance of return between each pair of securities in the asset universe. A major breakthrough in the in the practical utilisation of portfolio theory came with Sharpe's (1970) development of the market model (or single-index model). The major assumption of Sharpe's single-index model is that all the covariation of security returns can be explained by a single factor. One version of the model, called the market model, assumes that each asset's price movement can be related to the price of the market portfolio, which is a portfolio comprising a weighted average of all assets traded on the market. This market factor is assumed to be the only systematic force that impacts on all assets, while other effects are presumed to be specific or unique to the individual asset (Farrell 1983). The returns of the various assets in the asset universe are assumed to be related to each other only through common dependence upon this market index, and hence the necessity to specify the covariance of returns between every pair of assets is eliminated (Harrington 1987).

The market model generates a characteristic line by assuming that the return of an asset is determined by the market index (Dobbins and Witt 1983). That is:

$$R_i = \alpha_i + \beta_i R_m + \varepsilon_i \tag{2.3}$$

where R_i is the return of asset i over a particular period; α_i is the rate of return that is independent of the market movement; β_i measures the sensitivity of asset i returns with respect to R_m; R_m is the return of the market portfolio; and ε_i is a random error term (Dobbins and Witt 1983, Harrington 1987). The estimates of α_i and β_i are usually obtained from time series regression analysis (Elton and Gruber 1987).

A key assumption of the market model is that the only reason why assets vary together, systematically, is because of a common co-movement with the market. There are no effects beyond the market (for example industry effects) that account for co-movement between assets (Elton and Gruber 1987, Wagner *et al.* 1995). An asset's total risk is therefore sum of two components: that which is correlated with the market return, non-diversifiable (systematic) risk, and that which is independent of the market return, diversifiable (non-systematic) risk (Dobbins and Witt 1983, Harrington 1987, Wagner 1995). Since the systematic return is correlated with the market return, it may be expressed as a factor β (beta) times the market return. The coefficient β_i therefore indicates the expected responsiveness of an assets i's return to changes in the level of the market index (Dobbins and Witt 1983).

Thus, the expected return of an asset i, can be written as:

$$E(R_i) = \alpha_i + \beta_i E(R_m) \tag{2.4}$$

This equation breaks the return on an assets variance into two components, that part due to the market (systematic) and that part independent of the market (unsystematic) (Elton and Gruber 1987). The variance of an asset's return, σ_i^2, is given by:

$$\begin{array}{ccccc} \mathrm{Var}(R_i) & = & \beta^2 \mathrm{Var}(R_m) & + & \mathrm{Var}(\varepsilon) \\ \text{Total risk} & = & \text{market - related} & + & \text{specific risk} \end{array} \qquad (2.5)$$

The market-related component of risk is sometimes referred to as systematic risk as it is common to all assets; that is, it systematically impacts across all assets. The specific risk component is also reffred to as diversifiable risk since it is unique to the asset and can be reduced when assets are added to a portfolio (Farrell 1983).

The preceding discussion has implications as to the sort of risk that should be rewarded in the marketplace as well as to the relevant measure of risk for assets and portfolios. In particular, since diversification provides a way of eliminating unsystematic (diversifiable) risk from the portfolio, the market, in theory, is unlikely to reward it. It will only reward systematic (non-diversifiable) risk.

This market model was initially used by Sharpe (1970) to simplify the process of evaluating efficient portfolios in the Markowitz framework. Determining these portfolios involves following a similar procedure to that required by the original Markowitz formulation (Dobbins and Witt 1983). It requires the standard deviation of every asset's expected returns, the correlation between the expected returns for every pair of assets, and the amount of each asset being held with considerably reduced number of inputs. For instance with 20 assets, to calculate the portfolio risk would need estimates of 20 standard deviations and 20 correlations. The Markowitz model would have required 20 standard deviations and 190 correlations (Harrington 1987). Thus, the implementation of the Markowitz model is computationally burdensome for a realistic number of securities, and with the Sharpe simplification there is no requirement for direct estimation of the joint comovement of assets, only estimation of the manner in which assets move with the market.

To estimate the covariance between the returns of two assets you need only the variance of the market returns, which measures the magnitude of market changes, and β-coefficients, which measure the influence of market changes on the individual asset returns (Harrington 1987).

Although the Sharpe simplification resulted in the Markowitz model having much greater practical value, attention soon shifted to the development of the capital asset pricing model (CAPM). The market model provided the conceptual foundation for the CAPM. Whereas the Markowitz model deals with the concept of total risk, the market model focuses on the concept of systematic risk as characterised by β (Dobbins and Witt 1983, Harrington 1987).

The Markowitz mean-variance model was modified by introducing into the analysis the concept of a risk free asset, such as treasury bills or bonds. The risk-free asset is supposed to have zero variance and zero covariance with any other asset, while providing a small, but positive return (Harrington 1987). The risk free asset may be combined with any portfolio on the efficient frontier to yield a new portfolio. By introducing the concept of a risk-free asset, a new set of portfolios depicted by the capital market line is derived, which dominates the Markowitz efficient frontier. The individual is therefore able to move to higher level of utility than previously (Dobbins and Witt, Elton and Gruber 1987).

The portfolio's (except for market portfolio) or asset lying on the capital market line provide more return for the same risk, or they offer less risk for the same level of return as those on the Markowitz efficient frontier. This is because the investor is now able to borrow or lend at the risk free rate to supplement the investor's existing portfolio. The particular point chosen on the capital market line will depend on the individual's utility function, which will be determined by his attitude towards risk and expected return. This is shown by the utility curves in Figure 2.4.

Figure 2.4 shows that a risk averse investor would select a portfolio along the segment R_f–M by purchasing portions of the market portfolio (M) and of the risk-free asset (R_f). The more aggressive risk taker would borrow money and would hold portfolios along the segment M–Z by buying as much of M as possible. The average investor would hold the market portfolio M (Harrington 1987).

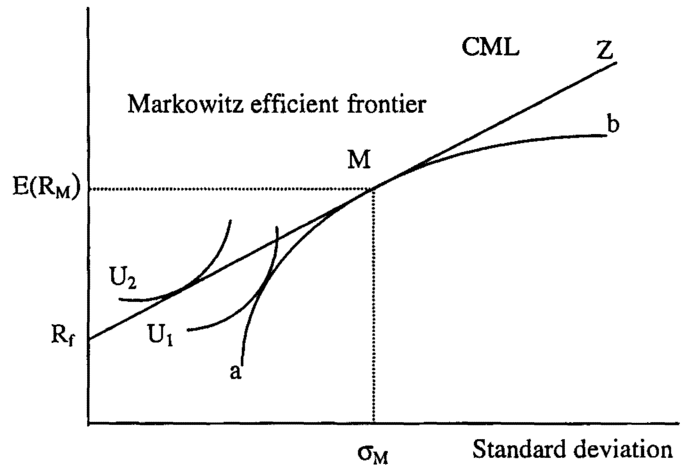

Figure 2.4. The Capital Market Line

As with all E-V models, the CAPM is suitable for decision making. In addition, however, it is simpler than other risk incorporating planning techniques and it does not require massive data input. The CAPM can also provide a measure of riskiness of each enterprise relative to the market and information on whether enterprises or activities are being adequately compensated for risk.

2.5 Conclusion

This review has suggested that the CAPM is relatively computationally simple and the quantity of data is much reduced. In addition, it is able to distinguish between diversifiable and non-diversifiable risk components, thereby allowing only that risk component which cannot be diversified to be focused on. Furthermore, the CAPM generates a range of information on the riskiness and return of alternative activities, which could be used intuitively by farmers to assist them with diversification decision. In chapter three, the capital asset pricing model is discussed in more detail.

3. The Theory of the Capital Asset Pricing Model

3.1 Introduction

The purpose of this chapter is to review the capital asset pricing model (CAPM). The derivation of the CAPM is mathematically rigorous; however, an intuitive approach is followed here. The CAPM can provide useful information for farmers and managers on risk management. Such a model can provide a measure of the riskiness of each enterprise relative to some chosen market index, and information concerning whether enterprises or activities are being adequately compensated for risk. The use of the CAPM in this report is to determine the impact of diversification into forestry on the risk and returns of sheep farming. Such a procedure measures the relative risk of an asset vis-à-vis the market (Ross 1978) and signals the amount of meaningful risk to an investor.

It was concluded at the end of Chapter 2 that the CAPM is an appropriate method of evaluating the risk and return of diversifying into forestry, which can be used by farmers to assist them with diversification decisions. Its computation is relatively simple and the quantity of data is much reduced. [Therefore, making the results easier to interpret.] In addition, it is able to distinguish between diversifiable and non-diversifiable risk components, and uses the mean-variance (E-V) efficiency criterion to order uncertain choices.

The first section of this chapter reviews the theory of the CAPM. Section 3.3 looks at the factors affecting the model. Whilst the final section provides a critique of the CAPM.

3.2 Theory

A number of simplifying assumptions underlie the CAPM (Harrington 1987). These are as follows:

1. Investors' choice of assets is based on the first two statistical moments of the normal distribution of possible asset returns. Return is measured by the mean returns expected from a portfolio of assets; risk is measured by the variance of these portfolio returns.
2. Investors are risk averse.
3. Investors have homogeneous expectations of risk and return.
4. All investors are price takers.
5. Information is freely and simultaneously available.
6. Total asset quantity is fixed, and all assets are marketable and divisible.
7. Investors have identical time horizons.
8. There is a risk-free asset, and investors can borrow and lend unlimited amount at the risk free rate.
9. There are no taxes, transaction costs, restrictions on selling short, or other market imperfections.

Most of the assumptions underlying the capital asset pricing model are restrictive in the sense that most of these assumptions are violated in the real world. The first seven assumptions generally hold reasonably well in the case of stocks, where CAPM traditionally has been applied. However, the eighth assumption—lending or borrowing unlimited funds at a constant risk-free rate—is seldom valid. Additionally, there are usually taxes, transaction costs, and information costs. But the CAPM approach has been widely applied despite these problems, indicating either its acceptance or robustness.

In the case of agricultural and forestry investments, the first five assumptions should hold as well as they do for stocks. [Whilst the sixth assumption would probably hold for agriculture.] Forestry investments, however, would certainly be less divisible than investment in stocks, and are less liquid as well. It may be possible that they would appeal to only to investors with long time-horizons, compared with farming, which may partially violate the seventh assumption. The lending and borrowing assumption applies no better, or worse to farming and forestry than to stocks. Overall, then it appears that forestry and agricultural investments generally conform to the CAPM assumptions. Despite these limitations, it is a widely used method of decision analysis.

The derivation of the CAPM follows from these assumptions and the mean-variance analysis discussed in the previous section.

The above assumptions imply that the investor can mix risk free assets with a universe of risky assets to construct a new set of possible investment portfolios as depeicted by the capital market line (Turvey, 1987), which is illustrated in Figure 2.2. The portfolios on this capital market line offer greater return for a given level of risk than portfolios on the Markowitz efficient frontier. The capital market line as shown in Figure 2.2 is the line that represents the different possible combinations of the risk-free asset and the market portfolio that any investor may choose to hold, depending on risk preferences (Brealy and Myers 1991). The capital market line establishes the return on an efficient portfolio but not on nonefficient portfolios or on indivdual assets. An extension of the portfolio theory into the Security Market Line allows for the estimation of such returns.

Sharpe extended the capital market line theory to all assets and portfolios, whether efficient or inefficient, by introducing beta as a measure of risk and the security market line to show the relationship between expected return and risk.

For a perfectly diversified portfolio the non-diversifiable risk component will be equivalent to total risk since it is not possible to diversify any further. That is, the correlation between the portfolio, σ_p, and the market, r_{pm}, is perfectly positive. However, for portfolios that are less than perfectly diversified or for individual asset, the non-diversifiable risk and total risk will not be equivalent, because they are less than perfectly correlated with the market. It has been established that the security market line which uses non-diversifiable risk as its risk measure and not total risk, is the appropriate risk-return relationship for assets and for portfolios that are less than perfectly diversified (Farrell, 1983). Hence the capital asset pricing model may be formulated (Sharpe 1964, Linter 1965) as:

$$E(R_i) = R_f + \beta_i[(R_m) - R_f] \tag{3.1}$$

where R_i is the return from the asset or portfolio, R_f is the return from the risk-free asset, R_m is the return from the market, and β_i is the volatility of an asset or portfolio relative to that of the market, *m*.

The CAPM formulation can be estimated by a statistical model that separates risk into its component parts. CAPM is based on the premise that, in competitive equilibrium, assets earn a premium over the riskless rate, and that this premium will increase as risk increases.

Because a return to the risk-free rate can be achieved by taking no risk (by definition), one should only include the value of returns greater than the risk-free rate in calculating a relevant risk measure. Jenson (1969) showed that the CAPM formulation is consistent with this rationale. Thus, most authors adjust the stated returns by subtracting the risk-free rate from both sides of the CAPM formulation to obtain the desired summary statistics. The model estimates the particular risk and return of an individual asset by regressing its annual percentage change in its value, less the risk-free rate, over time as a function of the expected returns of the annual percentage change of a market index of assets, less the risk-free rate. Hence, the identity to CAPM used to obtain various risk and return statistics (Jenson 1969) is:

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \varepsilon_{it} \tag{3.2}$$

where R_{ft} is the realised return of the risk-free rate at time t, and other terms defined in equation 3.1.

The error term is assumed to satisfy the usual properties of required by the linear regression model: it has a mean of zero and finite variance; the error terms are independent of each other; and R_m is independent of the error term (Sokal and Rolf 1981). The return on an asset may, therefore, be split into two parts, that which is perfectly correlated with the market return (systematic) and that which is independent of the market return (non-systematic) (Dobbins and Witt 1983).

The resulting estimates of beta and alpha are thus based on the returns in excess of the risk-free rate, the most relevant measure of market returns (Redmond and Cubbage 1988). This report calculated forest and agricultural returns using this risk adjusted method.

In the CAPM model, the beta coefficient, which is the relevant measure of risk, is calculated by regressing the annual percentage change in the index values for the individual asset against the values of the market over time. The Jenson index, which consists of a statistically significant alpha value from the regression (equation 3.2), indicates whether an asset's risk-adjusted returns is superior or inferior to the level of risk it assumes.

Theoretically, the CAPM rests on the efficient market hypothesis, whereby investors correctly price assets with the knowledge of all publicly available information (Bilek

1996, Cubbage *et al.* 1989). Thus the alpha value in the CAPM regression of an asset's returns upon the market's returns should be zero and should be located on the upward sloping line linking the risk-free rate of interest (on the Y axis) with the return of the market index (at a beta value of 1.0 on the X axis). Such a formulation describes the CAPM theory and the risk-return trade-offs that assets should exhibit under the efficient market hypothesis. A significantly positive or negative alpha (Y intercept), however, would indicate that the asset could be improperly priced or that there is more to an asset's appreciation than just the market factor. It would be advantageous for an investor to know when an asset is not properly priced vis-à-vis the degree of risk assumed, in order to invest in those assets with positive alphas (Cubbage *et. al.* 1989).

If we assume the efficient market hypothesis of the CAPM, the alpha value (Y intercept) for the regression should be zero because the market would correctly value the asset. However, analysts use CAPM to indicate instances where markets are not completely efficient and risk-return relationships are not accurately recognised (thus, the CAPM efficiency assumption is violated). This is true if CAPM is misspecified or if factors other than the movement of the overall market are responsible for an asset's appreciation. In such instances, a positive alpha significantly greater than zero indicates that an asset has an expected return greater that what the market would require for an asset in that risk class (as measured by beta), thus indicating superior risk-adjusted returns (Cubbage *et al.* 1989).

In addition to measuring risk-adjusted returns through the use of the CAPM, the beta can be used in portfolio analysis to derive mean-variance (EV) portfolios by minimising the portfolio beta subject to an expected return (Turvey *et al.* 1988).

3.3 Factors Affecting the CAPM

3.1.1 Return On Activities

The CAPM, as used for portfolio selection in business finance, measures return on activities on a 'rates of return' basis. The periodic return on an individual asset is measured as follows:

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}} \times 100 \tag{3.3}$$

where R_t is the percentage periodic return on an asset, P_t is the price of an asset at the end of the period, and P_{t-1} is the price of an asset at the beginning of the period.

The interval choice that is chosen for calculating historic returns is quite important. As it is possible that the systematic risk and the beta coefficients may be sensitive to the interval chosen for the regression. (Harrington 1987). The CAPM gives no guidelines for the choice of horizon, however it does rest on the assumption of normalcy. Based on this assumption, sampling theory dictates that a reasonable amount of data is needed to ensure a reasonable normal distribution, (Harrington 1987).

3.1.2 The risk free asset

The CAPM relies on the existence of a risk-free asset that does not covary with the market. In the absence of a true risk-free rate, a proxy such as the 90-day Treasury bill rate is often used. If this proxy is chosen zero variance can only exist for a single period – the single period of this one-period model (Harrington 1987).

Harrington (1987) suggests the use of a long-term government bond rate as a proxy for the risk-free rate, particularly when using the CAPM to look at assets that are clearly long lived, to overcome this problem. [Which is the case for forestry investment decisions.] However, the basic component of the risk-free asset is liquidity and consequently no default risk.

The New Zealand 90-day Treasury bill rate is free of default risk in the sense that one can be virtually certain that the government will pay interest on these bonds and will also pay them off when they mature. Therefore, the default risk premium on Treasury bills is essentially zero. However, an adjustment is needed for long-term Treasury bonds. The prices of long-term bonds decline sharply whenever interest rates rise, and since interest rates can and occasionally do rise, all long-term bonds, even Treasury bonds, have an element of risk called interest rate risk. These long-term bonds have also what is known as a maturity risk premium, which is higher the longer the years to maturity, must be included in the required interest rate (Brigham and Gapenski 1991).

Moreover, inflation alone makes the existence of a truly risk-free asset unlikely and makes the covariance of the least-risk asset with other assets vary likely (Harrington 1987, Farrell, 1983). Treasury bills are free of credit risk and because of their short term nature are virtually free of the interest rate risk. Deflating the Treasury bill rate can remove the impact of inflation thus making them riskless in real terms but not in nominal terms (Farrell, 1983).

3.1.3 The Market Index

A market portfolio in the capital market stock portfolio is a weighted average of all assets which can be traded and/or sold. Each asset is held in the market portfolio in the proportion that represents the proportion of that asset's total market value of all risky assets. For example if Carter Holt Harvey Forests represent 5 percent of all risky assets, then the market portfolio contains 5 percent Carter Holt Harvey Forest stock. This theoretical portfolio has to be a perfectly diversified portfolio. However, it is impossible to precisely determine the index and, therefore, a proxy is often used.

The application of the CAPM requires a market portfolio. This should ideally consist of all assets traded on the market. Such a perfectly diversified portfolio will only contain systematic risk and no non-systematic risk. Any departure from this weighted portfolio is likely to contain some non-systematic (diversifiable) risk. However, due to inadequate data, inclusion of all assets and their correct weightings, is virtually impossible. A beta coefficient derived form a limited size market portfolio could lead us to believe that non-systematic risk was larger or smaller than it actually was (Harrington 1987). The more representative the market proxy is of the true market portfolio, the more indicative the expected return from assets on the efficient market portfolio.

However, indexes are what investors use as benchmarks and thus, they can at least provide some practical information (Bilek 1994, Harrington 1987). Farrell (1983) concludes that results of various tests using various market proxies have been virtually the same regardless of the market index and this is in line with previous empirical studies that affirmed the risk-return relationship. Therefore, it is possible that investors can obtain usable estimates of market-risk parameters (betas) and gauge the risk-return relationship by using a generally representative market index. More narrow indices, such as one for agricultural returns, would be less relevant since they do not track the risk associated with a complete market basket of assets (Cubbage *et al.* 1989).

Because history is used as a proxy for the future the time period chosen can have an impact on the market return. Fama (1976) demonstrated that the variability (standard deviation) differs from one period to another. In addition to this there are also changes in the average realised return. He also concludes that the period should include a sufficient number of months to allow the construction of meaningful frequency distributions.

In New Zealand the market economy prior to June 1984 was heavily regulated having a profound effect on the behaviour of individuals as well as agriculture and forestry. Also, since 1984, other factors have changed – institutions such as the Reserve Bank of New Zealand control the money supply (Dalziel 1996), which ultimately affects interest rates and, therefore, the supply of money available for investing in the market. The Reserve Bank also has the responsibility of controlling inflation by law (Dalziel 1996). Furthermore, the period between 1984 and the present included the 1987-sharemarket crash and the 1993 price spike in forestry prices, for example. Thus, changes in economic conditions during this period could cause an adverse change in volatility (of the market proxy as well as the risk-free rate) for the period.

3.1.4 The Impact of Inflation

The impact of inflation is an intricate issue and is not well developed in CAPM analysis (Harrington 1987). Agricultural economists tend to deflate data for most problems, and it could be argued that analysing the 'real' variation rather than the 'nominal' variation is more appropriate. Collins and Barry (1986) adhere to this school of thought. Turvey and Driver (1987) state that inflation is not exactly predictable and can be a source of systematic risk and, therefore, the data should not be deflated. This view seems to be supported by the studies in the finance literature. For example, Van Horne (1986) maintains that as long as inflation is predictable, it is not a source of uncertainty and, therefore, the risk of a security can be described by its systematic and non-systematic risks, regardless of whether these risks are measured in real or nominal terms. However, it could be argued that not much unexpected inflation is expected to occur over a relatively short period. On the other hand, as far as investment decisions in forestry are concerned real prices are more preferred as they are much more stable due to the length of the forest rotation (Price 1989).

When evaluating an investment it is important to stress whether the prices used are in real or nominal terms. Otherwise a bias against the investment under consideration will result. The error is that a real rate is compared with a current rate (Gregersen 1985).

3.4 A Critique of the CAPM

The Capital Asset Priding Model is able to distinguish between systematic and non-systematic risks. This is important, as it allows an analyst to concentrate on systematic risk since non-systematic risk can be eliminated through diversification by an individual investor.

It was concluded in Chapter 2 that the CAPM is easy to compute and requires less data than the full variance-covariance model (than other models that are available for computing risk-return trade-offs). The CAPM provides a measure of risk which is, in theory, both objective and quantifiable; and provides a framework in which risk and return are considered at the same time; the security market line provides a direct and convenient way of determining the expected return on an asset.

The CAPM can be used to distinguish between diversifiable and non-diversifiable components of the total risk facing farmers, thereby allowing them to focus on the risk component which can not be diversified. The CAPM can provide a measure of riskiness of each enterprise.

The CAPM has been extensively tested. Various studies have examined the implications of relaxing the major assumptions upon which the CAPM is constructed. Jenson (1972) concluded that the results of such studies indicate that the theory is reasonably robust when these assumptions are relaxed. He added that many of these assumptions are not essential for the derivation of the important results of the CAPM.

Black, Jenson and Scholes (1972) and Fama and Macbeth (1973) have shown a strong positive relationship between risk and returns. The returns however, were not as great as the CAPM predicted. Farrell (1983) also concluded that empirical tests were generally consistent with some sort of risk-return trade-off in the marketplace.

However, Roll (1977) criticised these empirical tests of the CAPM and questioned the very testability of the CAPM. He claimed that empirical testing used only a proxy measure for the market portfolio. And unless the market portfolio is identified exactly, it is impossible to accept or to reject the CAPM. He argued that the market portfolio should include all risky assets and it should be mean-variance efficient. Even a small departure from the true market portfolio makes the test invalid. He further adds that identifying this market portfolio is a difficult task, as it requires some mechanism or ability to capture investor expectations. However, Copeland and West (1988) argue that many tests of the CAPM have shown that betas do contain ex-ante predictive power and a strong positive relationship between risk and return. They claim that Roll's arguments do not imply that the CAPM is an invalid theory, but that tests of the CAPM must be interpreted with great caution.

Farrell (1983) seems to support Copeland and West by suggesting that recent studies have shown that misestimation of the market proxy may have limited practical significance. He comments that investors can obtain usable estimates of betas and gauge the risk-return relationship by using a generally representative market index.

3.5 Conclusion

The model by its very nature is simple. The advantage of a simple model is that it is easier to understand, test, and use. Although we do not want a model that is so simplistic that it ignores important factors, a model's purpose is to abstract from the noisy complexity of reality. To be useful, a model must either describe what is occurring or forecast the future. A good model will both describe and forecast simply as possible. A complex model would be of marginal value if a simple asset pricing model could explain most of the variability of past returns and could predict the future with reasonable accuracy.

4. Methodology

4.1 Introduction

The preceding discussion of beta, and the mean and standard deviation of expected returns, and on the capital asset pricing model (CAPM) explains how risk and risk-adjusted measurements are estimated in theory. The first section details the assumptions used in the application of the CAPM model to the stumpage and agricultural price series. Section 2 provides details on portfolio analysis; whilst the third section provides details on the data sources.

4.2 Assumptions

Calculation of the mean and standard deviation for returns of an individual asset is calculated as the percentage change in value from one period to the next for each period in a time series. These returns would normally include dividends for the time period and do not need to be adjusted for market risk. Then the means, standard deviations, and correlation coefficients of all periodic returns are calculated and compared among investments.

The calculation of CAPM is more involved. The coefficients of the CAPM are estimated by using linear regression that relates returns for an individual asset (the dependent variable) to returns to the market as a whole (independent variable). In the recommended application, returns for both the individual asset and the market are based on risk-adjusted rates of change[1].

The market return for the Barclay's index is without dividends reinvested, whilst the NZSE40 index represents the return for stocks with dividends reinvested. This does not appear to affect the variance, however, it does affect the market return for use in estimating the market risk premium. This is illustrated in Table 4.1. Gross market returns (i.e., including dividends) between 1991 and 1996 showed, on average, an extra 2 percent return above the mean returns from the capital index (i.e., not including dividends). Assuming that this percentage remained constant over time, it would be the same percentage for the entire period of the series, effectively increasing returns by a constant of 2 percent. [Therefore, returns from the market index and the risk-free rate, for use in estimating the market risk premium and risk-adjusted rate of return, used returns for the period 1976 to 1996.] This would give a similar figure to that obtained by the New Zealand Treasury Department for use in calculating its capital charge out rate which uses a rate of anywhere between 6 and 10 percent[2]. A similar construct may be derived for the stumpage and agricultural price series. Stands of timber may not only appreciate or depreciate in price (like a stock), but also offer value appreciation each year because of biological growth—similar to investment in a long term bond with the chance for capital gain due to

[1] Appendix 1 illustrates how these risk adjusted rates of return were estimated for each price series.
[2] P. Anderson, Policy Analyst, New Zealand Treasury, Wellington, (pers. comm).

interest rate declines[3]. Thus, a better measure of a forestry stand's actual returns could be reflected in the sum of the stumpage price change plus growth. Akin to this is improved meat and wool breeds leading to higher returns. This total amount would probably more accurately reflect the total returns experienced by investors in forestry and agriculture. However, since dividends have only been included for market returns from 1991 to 1996, for estimation of the market risk premium only, these values have been omitted from the analyses.

Table 4.1. Comparison of the mean expected return and variance for the market index (with and without dividends) from 1991 to 1996

	Market Index (without dividends)	Market Index (with dividends)
Mean return	13.0	14.8
Standard deviation	25.9	25.7
variance	667	669

The estimate used for stumpage returns are for *Pinus radiata*, unpruned average across all grades for the Canterbury region. Investors normally would seek to buy forestry stands that grew at rates greater than the regional average. They would probably also manage their stands more intensively than this average. This is because the returns used for stumpage in the Canterbury region are probably lower than the national average due to the preponderance of lower site index and quality.

The use of aggregate price data can also underestimate the variability an individual farmer faces and consequently can result in the selection of unrealistic farm

[3] T. Bilek, Forest Economist, University of Canterbury, (pers. comm.)

enterprise portfolios (Debrah and Hall 1989). Farmers face variable incomes from year to year primarily because of variable weather conditions, disease and pest attacks, uncertainties in the input and product markets, the exchange rate, and inflation. Sheep gross margins per sheep stock unit increase moving from northern to southern regions; this reflects a corresponding trend of increasing per sheep performance and prices received (The New Zealand Meat and Wool Boards Economic Service 1996). These same risks could also apply to forestry. The CAPM estimates income risk from average prices received based on time series data. Even though aggregate price data tends to underestimate individual farm prices, applications based on the former are used in this report because a of general absence of long enough time series data for individual farms and forestry returns. [Although R. Davison[4], of the New Zealand Meat and Wool Boards' Economic Service, commented that "national average agricultural returns are generally indicative of regional returns."]

In this report it is assumed that all trees remained in the same product class, and only price appreciation in that class was measured for the period 1976 to 1996. This is because the only price series that was publicly available for the time period, which reflected returns across a range of unpruned radiata grades. It was not until the corporatisation of New Zealand's Forestry Service in 1987 that diversification into other product classes evolved. The traditional large unpruned radiata pine sawlog exports to Japan were joined by expanding sales of radiata pine pruned peeler logs, Douglas-fir sawlogs, larch peelers, and a range of miscellaneous softwood species

[4] R. Davison, Director of the New Zealand Meat and Wool Boards' Economic Service, (pers. comm.).

and log specifications (Birchfield and Grant 1993). Prices for these grades have only become available since 1993 and therefore would not be suitable for use in the CAPM, since the model requires the use of long-term data, especially for analysing forestry investment. The only other price series available was for Japanese A grade logs, and this series started in 1986. This series was not chosen, as it only represents one log type and would not be a realistic representation of different grades.

Stands can grow from one product class to another, increasing their value substantially, as opposed to lamb, which needs to be sold right away, or it becomes mutton resulting in less value, for example. Also, trees that are pruned and grown for clearwood may be worth two to three times as much on a per unit volume basis as unpruned trees. At the time of writing there is approximately a 70 dollar premium for pruned logs (Meares and McKenzie 1998).

Land was also excluded from the analysis, partially because no generally accepted series of forestry prices exists. Additionally foresters often exclude land from investment analyses, considering it a sunk cost. New investors would have to buy land. If land prices appreciated or depreciated the same amount as forestry prices, the CAPM results would be the same. If forestland prices changed less than timber, the returns (or losses) would be less than those based on the timber price series (historically). In practice, however, growing timber is usually the "lowest" use for a piece of agricultural land or forestland. Now prices for forestland are increasing forcing the price agricultural land up.

The analysis also excluded management costs for forestry investments and for agricultural investments. This approach is the conventional way CAPM is used to estimate returns for different assets (Cubbage *et al.* 1989). Forestry investments may require greater management than farming. Establishment, managing, and harvesting timber take some effort and expense. This is not forgetting that farming is also management intensive. Of course, intensive management may also increase growth rates substantially more than the average case used here, thereby greatly increasing returns. Purchase and sale of sheep assets is also not free, however, and these changes vary widely depending on time of year and production factors. Lamb and sheep sale prices, and the timing of sales would influence the weight and possibly the quality of meat. Therefore, farmers should consider these and management costs when comparing farming versus forestry investments.

If we assumed that land and growing stock values track stumpage prices, that timber growth is constant, and that management expenses are equal, then all of the variation in the constructed series of forest asset returns is caused by variation in the price of stumpage. Washburn and Binkly (1990), Thomson and Baumgartner (1988), Redmond and Cubbage (1988), and Wagner *et al* (1995) used this as a tenable assumption.

The illustration of the method thus far has assumed that one will use annual data in the CAPM model to estimate risk and returns. The same formulation may also be used with quarterly or monthly data as well, if they are available. This may allow use of more data points in the regression, thereby leading to greater explanatory power of the results. In this case all stumpage prices, agricultural prices, market prices, and risk-free returns would be calculated on a quarterly or monthly basis. Because of a lack of quarterly or monthly data for forestry returns (for the period under investigation), returns for stumpage prices, agricultural prices, market prices, and risk-free rate returns are reported as yearly averages.

The differences between this approach and traditional forestry and agricultural investment analyses should be noted. Foresters are apt to think of investments in terms of purchasing forestland, planting trees or performing other stand treatments, and making periodic harvests. Based on these cash flows, net present values or cash flow measures of returns could be calculated. Portfolio analysis, however, evaluates the changes in value over time of an individual asset and its relationship with respect to other assets in the portfolio, not merely as a stand-alone discounted cash flow analysis, even though the market value of an asset theoretically reflects the discounted value of estimated future cash flows. In the CAPM approach, returns to assets are not based on purchase and sale price plus cash flows, but rather periodic percentage changes in value or that asset for one firm vis-à-vis the market for all investors as a whole. This is not an evaluation of an individual, isolated investment, but rather one for all investors in a similar commodity over a fixed time period. This research examined the applicability of the CAPM approach for forestry, where regional stumpage prices serve as a proxy for the periodic returns for regional forestry investments, just as agricultural prices do for investments in farming.

Another distinction made in this analysis is the treatment of risk exclusively in financial (variation of stumpage and agricultural price) terms. Foresters tend to think of risk in biological terms such as loss from fire, insects, disease, or unfavourable weather. While these risks are present, they are generally small (Webb 1987). Yearly growth increase or product class improvements should more than offset these mortality losses as well as marketing or price risk. Thus, measuring returns strictly on a stumpage price basis should still provide a conservative estimate. Farmers are apt to think of risk in biological, marketing, and/or price terms. However, unlike forestry, yearly growth increases for sheep will not be offset by increased returns. In practice, the risk of holding an investment can be measured by the value of that investment at any point in time. This value may vary from zero (i.e., total firm bankruptcy, complete loss of a forest to a fire, loss of all lambs due to bad weather) to a positive value of forestry or agricultural asset (or any other asset for that matter) that reflects a fair price based on the supply-demand interactions of the marketplace. Systematic differences among farms or regions, due to soil fertility or management, for example, were not included in the variances. Similarly, systematic trends in yields, due to changes in technology or other predictable factors, were not included in the variances.

Note also that nominal returns were used for use in the estimation of the CAPM coefficients. This is based on the following rationale. In his study of inflation as a particular source of risk, Brake and Melichar (1977) commented that " inflation and the related instabilities in financial markets have brought new, significant sources of risks for many types of farmers." He described the effects of inflation on farmers in the following terms: "The changing relationships among and between prices of inputs and outputs under conditions of inflation has increased the volatility of farm income and thus increased farmers' risk position (p 27)"

4.3 Portfolio Analysis

Portfolio theory provides the methodology to determine which combination of assets gives the highest rate of return for any amount of risk. This can be attained by reducing variance or by increasing expected return, or both (Hardaker *et al.* 1997). Generally, this requires elicitation of the farmer's utility function to determine the optimum mix of risky assets to be included in the portfolio. Because the farmer's utility function is not known assumptions are made regarding his/her risk preferences, and bounds are placed on the level of risk aversion. The CAPM model assumes that investors are risk averse, therefore the objective is to minimise the variance whilst maintaining returns.

In terms of the CAPM, the only relevant measure of an asset's or portfolio's risk is its market (systematic) risk, which is the only risk that an investor can be rewarded for undertaking, can be reduced by careful selection of assets in a portfolio (Redmond and Cubbage 1988). The non-systematic risk of an enterprise can be reduced through diversification with assets that are weakly or preferably negatively correlated. Sharpe (1970) discusses the concept in terms of a portfolio of assets. When the non-systematic risk is omitted, the portfolio variance is simply the weighted average of the betas of the component assets. This is consistent with the methods employed by Collins and Barry (1986) and Turvey *et al.* (1988) for risk analysis using modern portfolio theory. This is measured by a portfolio's beta index as defined by equation 4.1.

$$\sigma_p^2 = \left[\sum_{i=1}^{n} x_i \beta_i\right]^2 \sigma_m^2 \tag{4.1}$$

where σ_p^2 is the portfolio variance, σ_m^2 is the market index variance, and x_i is the percentage weight of each asset held in the portfolio.

According to the New Zealand Meat and Wool Boards' Economic Service, income on the average sheep farm is derived from approximately 40 percent lamb, 30 percent mutton, and 30 percent wool based on the total effective grazeable area[5]. These were the percentage weights used for analysing the risk and return for the agricultural portfolio. Appendix 2 presents the portfolio composition, and its risk and return, with the addition of forestry. For the purposes of this analysis, it was assumed that with an increasing or decreasing investment in forestry there was a proportionate decrease or increase in the percentage of the agricultural assets held in the agricultural portfolio. This allows for the formation of a minimum variance frontier.

[5] R. Davison, Director of the New Zealand Meat and Wool Boards' Economic Service, (pers. comm.).

In addition to identifying the risk-return frontier, average unimproved areas of the average total sheep farm area for various regions were identified which could potentially be used for forestry. The total effective area, areas already in forestry, and unimproved areas were converted to a percentage of the total farm area for each respective region. The areas that are already in forestry and the areas not being utilised were summed to obtain a percentage for the total area available for forestry. The percentage of income derived from each agricultural asset, without the addition of forestry, used the same weights as the agricultural portfolio, i.e., 40 percent lamb, 30 percent for both mutton and wool. The weights of the agricultural assets for use in the portfolio composition with the addition of forestry were obtained by taking the percentage of income derived from each activity as a percentage of the total effective area, with the remainder being in forestry[6].

4.4 Data - activity returns for the model

Data for the evaluation of forestry investments were obtained from stumpage price series for unpruned–average across the grades for Canterbury *Pinus radiata* price trends within 80km of Christchurch[7]. Data for the evaluation of agriculture investments were attained from and national average export schedule prices across all grades for lamb and mutton, based on dollar per head returns including skin and wool payments, and the average segment indicator price for clean wool (cents per

[6] See Appendix 3 for details.
[7] Log grade returns were obtained from the Ministry of Forestry, Christchurch, (pers. comm.) (Appendix 1).

kilogram)[8]. Stumpage prices alone may not perfectly represent the rate of change in forestry value over time, but they are the best available gauges of forestry values, which probably parallel the income-producing capability of the land. As stumpage prices increase, one would expect land prices to increase. While there appears to be no research that has empirically tested this premise, the swing towards converting farmland to forestry in New Zealand has seen prices for farmland remain buoyant, despite the cyclical returns from sheep and wool (pers. observ.).

Theoretically, the CAPM is a single period model relying on historical price series data, therefore, the period chosen should reflect the investors time horizon for expected returns. That is, by choosing a particular interval investors are not reallocating their portfolios; that is, they are not buying and/or selling their assets (Harrington 1987). For radiata pine, the time period for a single economic rotation, is approximately twenty-five years. Whereas, the time period for farming returns is yearly. Already this assumption has been violated, however, this is generally overcome by including a reasonable amount of data to rest on the CAPM's assumption of normalcy. Based on this assumption, the data reported was analysed using average annual price data for the period 1976 to 1996. Data for the agricultural returns used in this report was not available prior to 1976. Agricultural, market, and the risk-free rate returns for each month were averaged to determine a yearly return. Stumpage returns were reported as the average price returns for the year.

[8] Agricultural returns were obtained from the New Zealand Meat and Wool Boards' Economic Service, Wellington, (pers. comm.) (Appendix 1).

The use of annual stumpage and agricultural prices as a proxy for forestry investments also has a corollary in the use of the Barclay's and NZSE40 as a market index[9] for stocks. In traditional CAPM analysis, the periodic returns for one asset (including dividends), adjusted for the risk-free rate[10], are regressed against those of an adjusted market index. Stumpage prices represented the annual percentage change in stumpage value, as the Barclay's and NZSE40 represented the market for all investments as a whole. The CAPM was then used to estimate alpha and beta values.

[9] Stock returns were obtained from F.Aldrdge, New Zealand Stock Exchange, (pers. comm.) (Appendix 1).
[10] The risk-free rate returns were obtained from P. Anderson, New Zealand Treasury, Wellington, (pers. comm.) (Appendix 1).

5. Results

5.1 Expected Returns

Table 5.1 lists the nominal expected value of annual returns and the standard deviations for lamb, mutton, wool, forestry and the market index for the period 1976 to 1996 without any adjustment being made to adjust for the risk-free rate. The standard deviation of returns, which is a measure of annual fluctuations (or volatility), for lamb mutton and wool shows greater variability relative to expected value of annual returns. Forestry returns exhibit less variability than lamb, mutton, and the market, but this is commensurate with lower returns. This volatility can be seen in Figure 5.1 where it is apparent that lamb and mutton returns fluctuate more widely than wool and forestry, indicating the stability of forestry returns.

Note that the return value for the market index includes dividends reinvested for the period 1991 to 1996. Therefore, the percentage returns calculated are lower than otherwise would be expected. However, the standard deviation of the market returns is consistent with those reported elsewhere.

Table 5.1. Expected value and standard deviation of yearly average annual returns from the agricultural and stumpage price series, and market index, 1976-1996

Price series	Expected value change of annual returns (percent)	Variance of returns σ_i^2	Standard deviation of returns σ_i
Lamb	10.0	644.1	25.4
Mutton	14.8	1793.5	42.3
Wool	5.1	303.2	17.4
Forestry	5.5	118.0	10.9
Market	14.8	669.6	25.9

5.2 Correlation Coefficients

Table 5.2 summarises the correlation coefficients for each of the assets. Lamb and mutton are highly correlated, and this is to be expected. The correlation between wool, mutton and lamb is almost zero, whilst similar results were observed between forestry, mutton and lamb. This indicates that the returns are uncorrelated. This is an extremely important relationship for investment analysis. Diversification can provide substantial risk reduction if the components of a portfolio are uncorrelated.

Table 5.2. Correlation coefficients for annual agricultural and stumpage returns, 1976-1996

	lamb ($/head)	mutton ($/head)	Wool (¢/kg)	Forestry ($/m^3)
Lamb	1.00			
Mutton	0.78	1.00		
Wool	0.05	0.09	1.00	
Forestry	0.01	0.05	-0.14	1.00

Forestry and wool show negative correlation. This indicates that it is possible to combine them in a manner that will eliminate risk. These results indicate that forestry has the greatest diversification potential.

5.3 CAPM Regressions

The independent (market portfolio) and dependent variables (individual activity returns) used to generate the characteristic line, and hence beta and regression coefficients, were discussed in chapter 4. The CAPM regression results are presented in Table 5.3 using nominal returns with adjustments made for the risk-free rate. The results are informative. The alpha values for all but three of the data series are negative, with only wool and forestry at significant levels. As noted previously, significantly negative (*positive*) alphas indicate returns less (*greater*) than the market expects for that risk level, either because markets are not entirely efficient and therefore the asset is mispriced, or because there is some non-market factor which results in a inferior (*superior*) return. A significantly negative alpha parameter for wool and forestry indicates the asset's returns are less than that necessary to compensate for a given level of non-diversifiable risk.

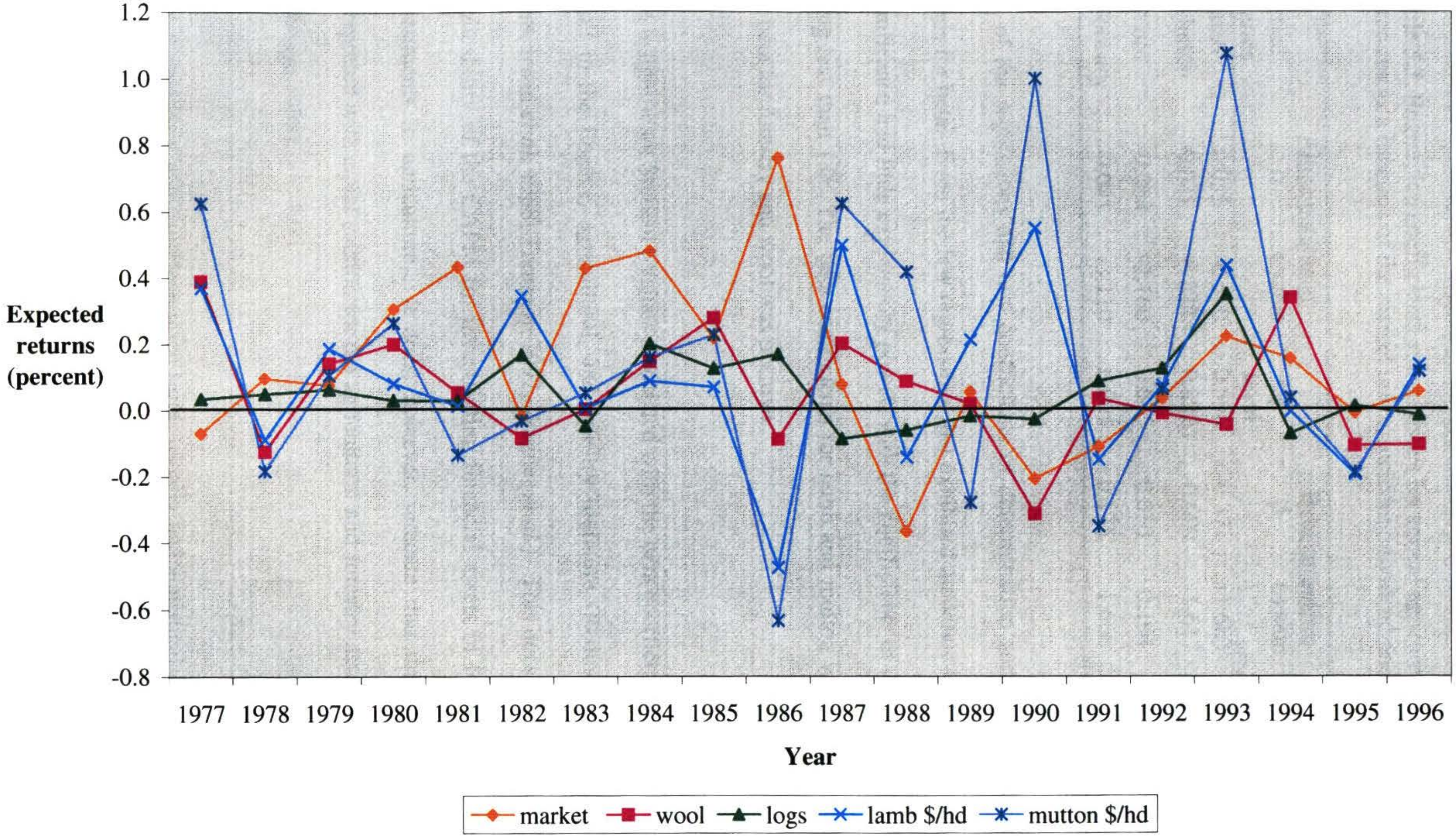

Figure 5.1. Mean returns for the agricultural and forestry assets, and the market index, for the period 1976 to 1996

Table 5.3. Regression coefficients and statistics for annual agricultural and stumpage returns as a function of the market index, including dividend returns from 1991

	Alpha parameter			Beta parameter			
Price series	α	t-value	sig. level	β	t-value	sig. level	R^2
lamb	0.035	-0.540	0.596	-0.371	-1.683	0.110	0.132
Mutton	0.021	0.228	0.822	-0.609	-1.617	0.123	0.127
Wool	-0.084	-2.160	0.045	0.030	0.194	0.848	0.002
Forestry	-0.081	-3.110	0.005	0.175	1.668	0.113	0.133

All of the regressions had low coefficients of determination and low significance levels for beta. Even the few regressions that exhibited moderate levels of statistical significance had little explanatory power, with the coefficients of determination (R^2) being less than 1.0. The beta coefficients for lamb and mutton was negative whist the beta for forestry and wool was positive.

The insignificant Student t-values associated with the beta coefficients are a common result in the finance, agricultural, and forestry literature (Redmond and Cubbage 1988, Irwin *et al.* 1988, Thomson 1992, Wagner *et al.*). This does not invalidate the applicability of the CAPM for investigating financial assets of forest management investments in agriculture. It does, however, indicate that the results must be interpreted with equal caution for the agricultural and forestry assets (Redmond and Cubbage 1988).

The agricultural and stumpage price series usually had statistical characteristics that were acceptable for use in the CAPM model. The assumption of normality was tested. Normality could not be rejected for the returns from any of the data series.

All were normal based on examination of the residuals, which indicates that they were statistically acceptable for CAPM estimation (Appendix 4). Overall the fairly satisfactory results support the statistical validity of using simple linear regression to estimate CAPM parameters for stumpage and agricultural price risk and returns. The normality supports the hypothesis of non-bias periodic returns. The normality of returns also indirectly supports the hypothesis of market efficiency (Redmond and Cubbage 1988).

5.4 Portfolio Analysis

The calculation of the market return (R_m) and risk-free rate (Rf), including the NZSE40 gross market index returns for the period 1991 to 1996, was 14.8 percent and 8 percent, respectively. This yielded a risk premium of 6.8 percent. This is within the range used by the New Zealand government. [The government uses a risk premium of anywhere between 4 and 8 percent[1].]

Each assets' risk adjusted discount rate is presented in table 5.4. The estimates of the systematic $(\beta_i\sigma_m)^2$ and non-systematic variation ($\sigma_{\epsilon i}{}^2$) for each of the four assets are also shown in table 5.4. Lamb and mutton show the highest amount of systematic and non-systematic risk compared with wool and forestry. Wool exhibited very little market risk indicating that most of its risk is non-systematic. Forestry exhibited low

[1] P. Anderson, Policy Analyst, New Zealand Treasury, Wellington.

systematic and non-systematic risk indicating that it would be preferable in a diversified portfolio.

Table 5.4. Risk-return measures for the activities included in the portfolio model

Asset	Systematic risk $(\beta_i\sigma_m)^2$	Non-systematic risk $\sigma_{\epsilon i}^2$	Expected return (percent) $\overline{R}$
Lamb	9.60	17.62	5.48
Mutton	15.75	27.72	3.86
Wool	0.79	19.21	8.21
Forestry	4.52	10.13	9.12

note: these figures are expressed as standard deviations

Table 5.5 shows the total, systematic and non-systematic risk for the agricultural and forestry portfolios as well as the nominal expected returns for forestry and sheep farming.

Table 5.5. Total, systematic, and non-systematic risk measures and expected return for the agricultural portfolio with and without the addition of forestry

Portfolio	Total risk σ_p^2	Systematic risk $\beta_p^2\sigma_m^2$	Non-systematic risk $\sigma_{\epsilon p}^2$	Expected return $\overline{R}$
Agriculture	22.3	8.3	14.0	5.8
Forestry	14.6	4.5	10.1	9.2

note: these figures are expressed as standard deviations

Figure 5.2 shows the market risk return frontier for agricultural investment, forestry investment, and agricultural and forestry investments combined. The agricultural portfolio is applicable to those who wish to invest only in sheep farming. The forestry portfolio is applicable to those who wish to invest only in forestry. The points in between represent the frontier that is appropriate for farmers considering both investment vehicles. However, what is of importance is that the agricultural portfolio's market risk is reduced with increasing investment in forestry.

In Figure 5.2, the agricultural portfolio shows a maximum return of 5.8 percent with a market risk of 8.3 percent. The forestry portfolio shows a maximum return of 9.2 percent with a market risk of 4.5 percent. The lowest risk portfolio has a market risk of 0.02 percent and a return of 8.0 percent. It results from a portfolio of 65 percent forestry, 14 percent lamb, and 10.5 percent for both mutton and wool respectively[2]. It is important to stress that not all risk is eliminated, as there is still an element of non-systematic risk present (see Appendix 2).

The line in Figure 5.2 doubles back because the returns to the portfolio approximates a return to the risk-free rate, which has zero variance and a return of 8.0 percent. Since it is impossible to do better than the risk free rate the line starts to slope upwards with a corresponding increase in risk and return. The hyperbolic curve in Figure 5.2 indicates that the agricultural and forestry portfolios are not perfectly correlated, thereby showing that diversification gains effectiveness as the correlation between assets decreases.

Figure 5.2 shows the minimum variance set (line A-MVP-F), which is a locus of risk and return combinations that minimises the portfolio standard deviation for a given

[2] Appendix 2 presents the portfolio composition and its risk and return for some other points on the frontier.

level of return. Rational investors will only select portfolios on the minimum-variance set.

The minimum-variance set can be divided at the MVP into a top and lower half. Investors prefer portfolios on the top half, which are more efficient because the return is greater for a given level of risk. In Figure 5.2 an investor prefers portfolio *H* to *L* because *H* has a greater return for the same level of risk. While both portfolios are on the minimum variance set, only *H* meets the criterion for being more efficient.

A rational investor will select an efficient portfolio, which is a portfolio along the line MVP-F. Individual preferences regarding risk and return determine the choice of optimal portfolio along this line. An extremely risk-averse investor will select a portfolio close to or on the MVP, while a more adventurous investor will select a portfolio with greater risk and return. Utility functions and indifference curves allow more systematic examination of the concept of optimal portfolio formulation.

Figure 5.2 shows three imaginary indifference curves for utility levels $U_1 > U_2 > U_3$. The gradient of these curves will be steeper the more risk averse the farmer is, assuming that the farmer is risk averse, which is in accordance with the CAPM.

Inspection of Figure 5.2 reveals that, for the degree of risk aversion expressed in the indifference curves, MVP is the best alternative, as it is located on the highest indifference curve. It represents the lowest market variance for a given level of expected return. Alternative F with the highest overall expected return offers the highest return with average market risk compared with alternatives P and A. Option A shows the highest percentage of market risk with the least return.

Figure 5.3 shows the total risk return frontier for agricultural investment, forestry investment, and agricultural and forestry investments combined. The total risk frontier in Figure 5.3 shows a maximum return of 9.2 percent with a total risk of 14.7 percent. This is the result for investing in forestry only. The lowest risk portfolio has a total risk of 13.7 percent and 8.5 percent, as depicted by the point MVP. The highest risk portfolio has a total risk of 22.3 percent and a return of 5.8 percent. This portfolio consists solely of agricultural assets.

The line AF depicts the minimum variance frontier and movement along this line represents a trade-off between total risk and return. A rational investor will seek a portfolio along the line MVP-F. Where MVP represents the minimum variance portfolio. This portfolio consists of 75 percent forestry, 10 percent lamb, and 7.5 percent for both mutton and wool respectively.

Comparing the market and total risk frontiers shows that a portfolio consisting of both agriculture and forestry will lead to a point of utility maximisation for the farmer, assuming that the farmer is risk averse. Hence, the agricultural portfolio's systematic and non-systematic variation is diversified away with the inclusion of the forestry asset.

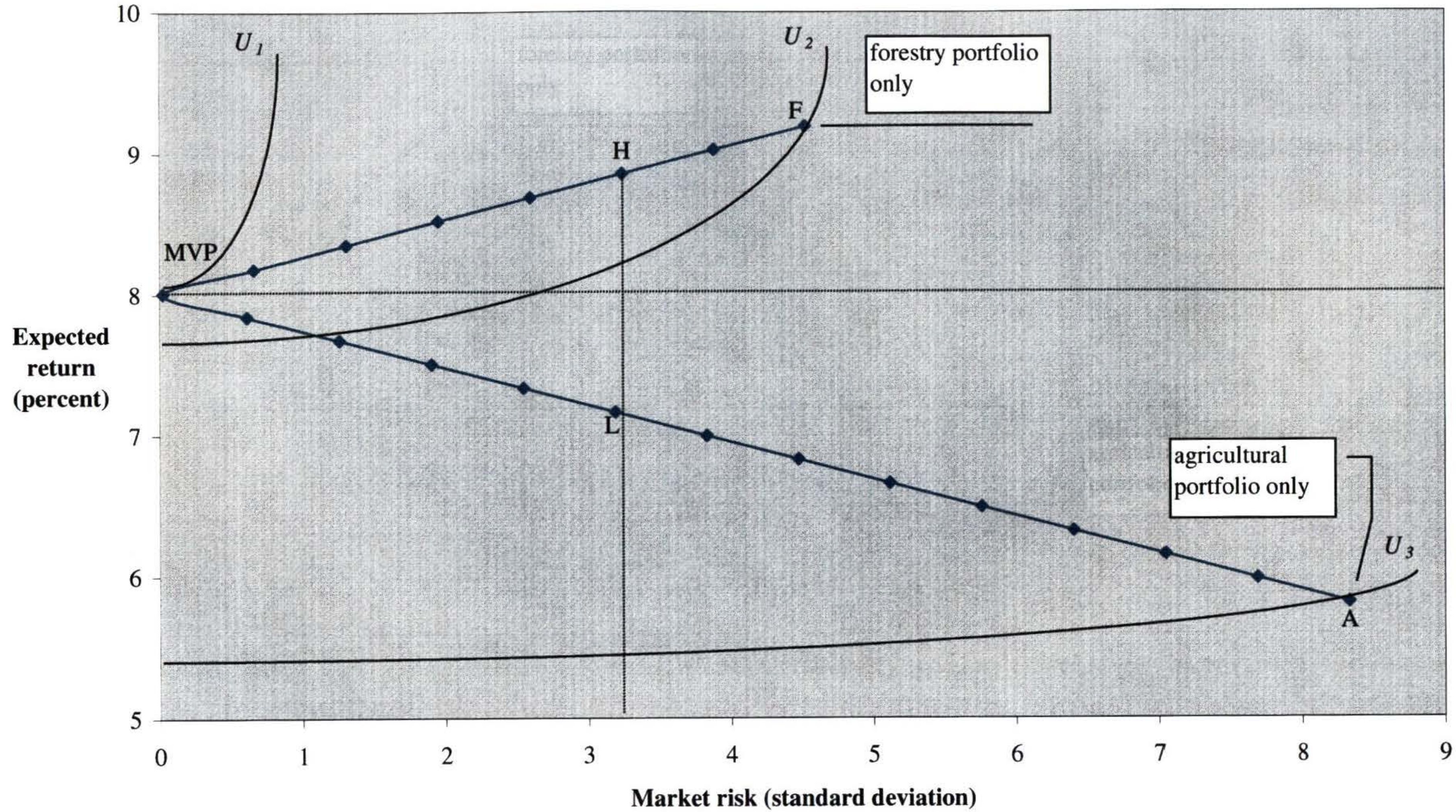

Figure 5.2. The market risk-return frontier for agricultural invetment, forestry investment, and agricultural and forestry investments combined

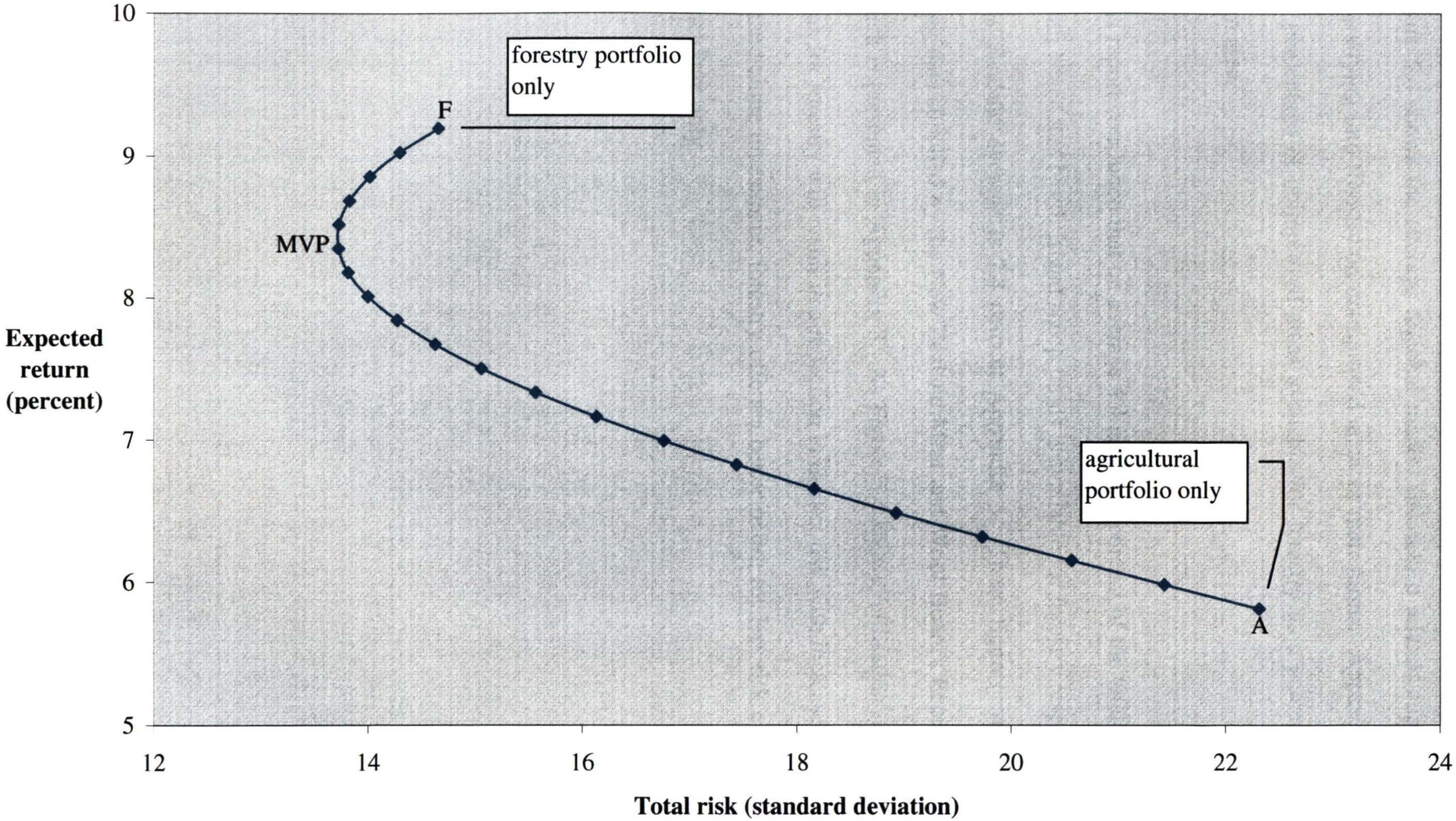

Figure 5.3. The total risk-return frontier for agricultural investment, forestry investment, and agricultural and forestry investments combined

Figure 5.4 shows the average regional market risk-return relationship for farmers' diversifying into forestry on unimproved areas of their farms. Appendix 3 presents the percentage of unimproved areas available for forestry as a percentage of total farm area.

This report concluded that on average 4.4 and 12.8 percent of the total farm areas of South Island and North Island sheep farms is available for forestry respectively. The New Zealand average is 7.4 percent Appendix 3. These figures were calculated using data supplied by the New Zealand Meat and Wool Board's Economic Service which is presented in Appendix 3. As Figure 5.4 shows, utilisation of unimproved areas for forestry will result in a reduction in market risk with increased returns. As a stand-alone investment, forestry offers a better return for less risk compared with agriculture only.

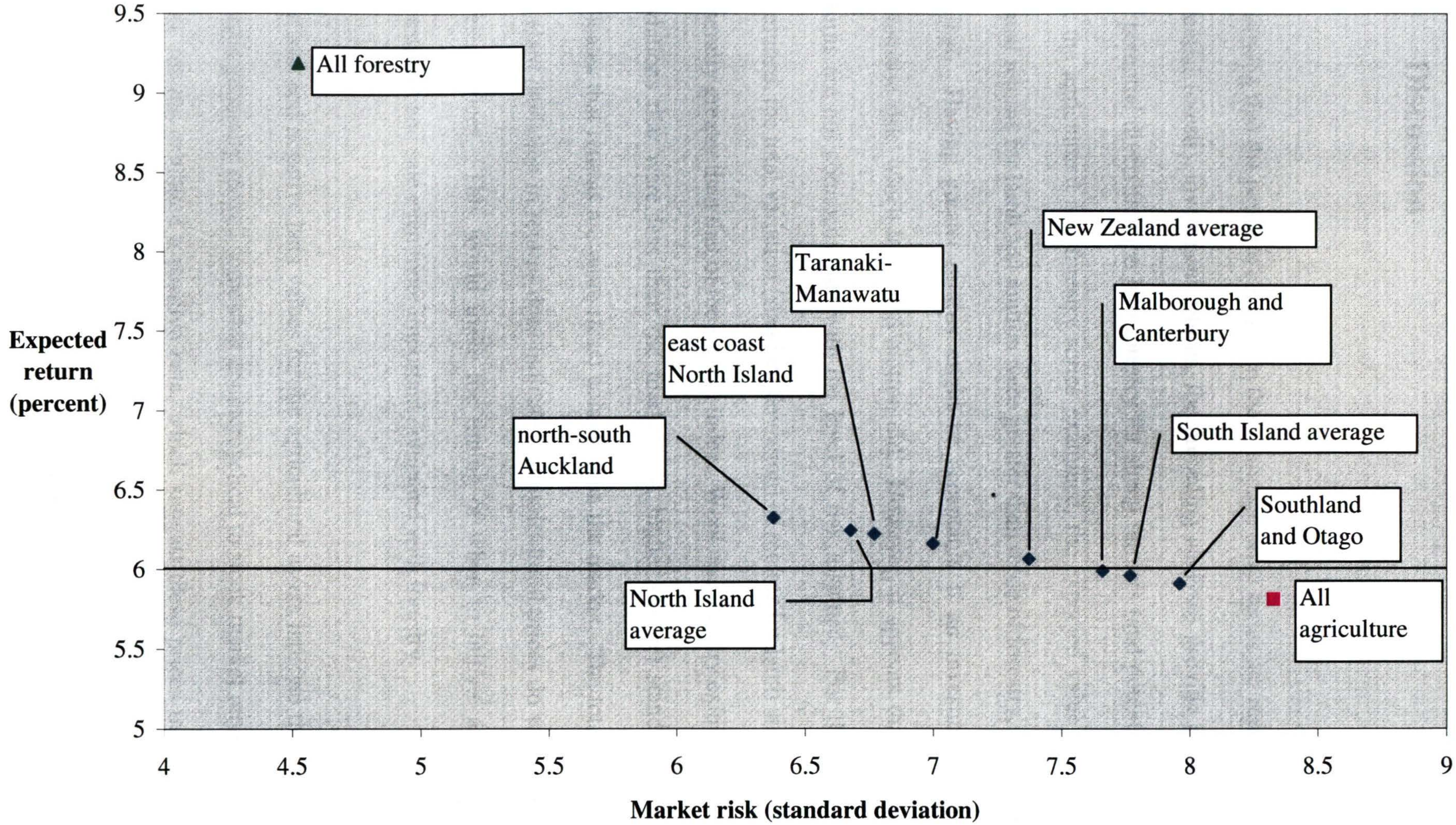

Figure 5.4. Average regional risk-return relationhsips for farmers diversifying into forestry on unimproved areas of their total farm areas

6. Discussion

Assuming that the periodic changes in the stumpage price series are representative of potential forestry investment returns, the preceding analyses provide many insights for potential diversification into forestry for sheep farmers (and potential investors). For the agricultural and forestry series examined, the expected value of change of annual returns for lamb and mutton were greater than those of forestry, wool, and the market. Having greater returns might be acceptable if an investment has high systematic risk, which lamb and mutton did. However, it appears that agricultural returns are not commensurate with the level of risk assumed. For the time series examined, the total variation (standard deviation) of returns for lamb and mutton was generally greater than that of the market index. Wool and forestry exhibited standard deviations that were less than the market. A higher (*lower*) standard deviation indicates that returns are more (*less*) volatile than the market. The total variation or standard deviation in returns does indicate that agricultural prices do vary more than forestry prices. This would make the timing of when to initiate an agricultural investment and sale even more important compared with forestry.

The low and negative beta values for the agricultural assets indicate that these price returns generally moved somewhat countercyclical to stock market returns. Forestry price returns exhibited a positive beta, which suggest these prices moved more in correlation to the overall market. The differences among beta values and low R^2 values suggest that there are influences on returns other than the market, which might be explained by the nature of the assets and markets. The differences may be partly explained by geographic and product differences. For agriculture this could be attributed to the unique supply and demand conditions of agriculture, which is largely determined by overseas markets and through the government subsidisation, protection, and intervention during the 1970's and 80's. The government up until around 1988 influenced domestic forestry price returns. The removal of government price intervention coincided with economic reforms to encourage growth generating a steady demand for timber, both locally and internationally. This derived demand is indicated to some extent by the expected returns for the forestry products that are higher than the agricultural assets, with less variation. In essence, the lower variation in these returns indicates the stability of forestry in the market.

Figure 5.1 shows that forestry returns do not fluctuate as markedly as agricultural returns. This coupled with the low and negative correlations of lamb, mutton, and wool, with forestry indicates that investment in forestry has the potential to smooth out price fluctuations in an agricultural setting. Offsetting price fluctuations in agriculture also has a corollary in annual growth dividends for forestry. For forestry, the "buy and hold" strategy has greater merit than for farming. Annual growth "dividends" will increase continually, offsetting price fluctuations. Stands may also grow into higher-valued product classes, the opposite is true for farming, however. Investment in plantation forestry is an investment in "biological growth" occurring at approximately 7 percent per annum in the volume of wood in the plantation[1]. This occurs totally independently of any economic perturbations. As the trees reach the latter stages of their growth, the economic elements of price by log grade increase. As an investment, forestry is an appreciating asset, which even if prices for the product fall has the capability offset those losses through volume growth[2].

The results of the analyses have several implications regarding investment in forestry for the sheep farmer of New Zealand. The preceding analyses showed that lamb and mutton had relatively high amounts of systematic risk compared with wool and forestry vis-à-vis the market port used in this study. [Whereas all of the agricultural assets had high non-systematic risk compared with forestry.] It is interesting to note that the inclusion of each of the agricultural assets in the agricultural portfolio reduces the systematic and non-systematic risk of the portfolio. Although wool exhibited less systematic risk compared with forestry, modern portfolio theory examines the merit of investing in individual assets based on how they contribute to one's overall mix of assets. Depending on an investor's risk tolerance, as discussed in Chapter 2, a desirable portfolio should have a mix that includes some assets with low levels of correlation of returns to that of the portfolio under investigation to perform well under varying market conditions. It may be possible to encounter assets that have good rates of return, yet have a fairly low amount of systematic risk. Based on stumpage price trends, forestry seems to be such a desirable asset. It not only achieves reasonable returns over a business cycle, it adds a risk reduction factor to the agricultural portfolio. It serves as an asset that is less than perfectly correlated

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[1] McKinlay Hendry Ltd, Investment Advisors, (pers. comm.).
[2] T. Bilek, Forest Economist, University of Canterbury (pers. comm.).

with the overall agricultural assets and, therefore, will reduce the deviation of the returns for the agricultural based portfolio.

According to portfolio theory (where forestry could be included with other assets such as sheep assets) and the capital asset pricing model, the concern is with the choice of efficient combinations of assets resulting from benefits of diversification across different assets. It is not important that lamb and mutton had high variability of returns. In combination with other assets, such as forestry, the only risk that is meaningful is a portfolio's systematic risk. As discussed earlier, portfolio theory has shown that if systematic risk is low or negative, then the risk for the entire portfolio is reduced. In the agricultural portfolio a decision maker may want to include forestry with its relatively high expected return and low systematic risk. A farmer could take advantage of the risk reduction characteristic and concentrate on investment in forestry in order to achieve high nominal expected returns with less volatility. The remaining non-systematic risk that is attributed to the unique supply and demand conditions of agriculture could also be eliminated by effective diversification into forestry, as illustrated by Figure 5.3. Naturally, many other investment characteristics, such as tract size, site quality, management, intensity, species mix, and accessibility, are also important in determining returns, just as the individual characteristics of any other asset, including agricultural assets, determines its performance.

The results indicate that for a farmer who chooses to diversify into forestry increase returns and decrease risk. However, under the CAPM assumption where investors are risk averse, the objective is to minimise market variance, i.e., by obtaining the least risk portfolio, the farmer will have a utility function represented by the curve U_1. This is the point MVP in Figure 5.2. It represents the lowest market risk portfolio with a risk of 0.02 percent and a return of 8 percent. The portfolio comprises of 65 percent forestry with the remainder being sheep. This compares to a market risk and return for the agricultural portfolio of 8.3 and 5.8 percent respectively. this is represented by point A in Figure 5.2 .

A sheep farmer whose risk preferences are risk adverse and is interested solely in agricultural investment will have a utility function represented by the curve U_3. If the farmer had a higher utility level that was represented by the curve U_2, and was willing to except greater risk for a higher return, then the farmer could invest purely in forestry.

It seems reasonable to assume that most farmers will consider investing in both forestry and sheep. Therefore , the weighting of the portfolio would be based on the amount of systematic risk the farmer wants in his portfolio and on compensatory returns for holding this risk. Ultimately the selection would be based on the farmer's attitudes toward risk as well as on the feasibility of the portfolio, given available resources. Depending on the farmer's risk preferences the farmer could choose a portfolio which minimises market risk anywhere along the line A-MVP-F in Figure 5.2. Although according to portfolio theory a farmer should only choose a portfolio along the line MVP-F as highlighted in Figure 5.2. Because for the same level of market risk the farmer can obtain a higher rate of return compared to investing on the line A-MVP. Where the farmer invested along this line would depend on his/her risk preferences.

Reducing the market risk offers a strategy for reducing exposure to changes in the market economy. It allows farmers' asset and product flexibility; which is further related to market flexibility. Forestry allows for asset flexibility, whereby investing in assets that have more than one use an enterprise yields more than one product with varying end uses. This allows the farmer to sell forestry products in different markets that may not be subject to the same risks as agriculture. Therefore, diversification into forestry further enhances the flexibility of the farm enterprise. This refers to the ease and economy with which the farming business can adjust to changed circumstances. Because of time flexibility and the countercyclical nature of forestry returns with sheep returns, farmers have the option of selling short in times of financial difficulty, thereby enhancing the strategic risk management of the farm. There are a number of options currently available to farmers:

1. *Forestry Joint Ventures* – may be registered under the Forestry Rights Registration Act 1983 where an investor can enter into a Joint Venture Agreement with the land owner to develop forestry. The income is shared by the parties in proportion to each party's contribution to the investment. As with individual ownership, the parties are entitled to deduct certain forest development expenditure against their income from another source.

2. *Partnerships* – security for the partners is provided through a legal contract and each partner qualifies for deductions and depreciation provisions under current taxation regimes. A partnership may register a joint venture under the Forestry Rights Registration Act 1983 with a landowner.

For farmers to reap the reward of financial gains at the end of the rotation it is important that a system for assessing quality is installed. With increasing plantings of trees being carried out by small owners, is important that the quality of the end product is guaranteed. Already one prominent New Zealand forestry company, Rayonier, has implemented a policy of guaranteeing its product to overseas markets through, for example, pruned log indexing (PLI) (pers. observ.). Coupled with this is the Forestry Research Institute's (FRI) pruned stand certification (Somerville 1995.).

With an increasing number of sheep farms being converted to forestry, the results provide insights for farmers wishing to convert part or all of their land to forestry. Most farmers can identify a part of their farm that is not productive. Figure 5.4 gives an indication of the likely risk-return trade-off that can be expected if non-productive areas of farms were to be utilised for forestry. Consequently, if a farmer were to convert unimproved areas to forestry risk would be reduced coupled with higher rate of return. Farmers have traditionally only used marginal land for planting trees without displacing too many stock units. However, if the farmer were to adopt the minimum variance portfolio (MVP), as highlighted in Figure 5.2 as recommended in this report, it would be expected that productive land would be utilised as a result of the diversification into forestry. This could result in reduced stock numbers, however, there would be a corresponding decrease in risk with increased returns. It has also been shown that forestry planting on ex-pasture sites can result in an increase in volume and yields of standing timber at the end of the rotation (West ?), therefore, offering potentially higher returns. There are also additional benefits once the trees are established such as shelter, which can result in increased lambing percentages and live-weight gains.

The expected returns for forestry were calculated using stumpage returns from the Canterbury region. A farmer in other regions could expect to get higher returns due to differences in site index, wood quality and silvicultural regimes, thus, offering the farmer potentially higher returns. Therefore, another option available to farmers is to invest in forestry off-farm. A farmer in the Canterbury region, for example, could spread risk through spatial diversification meaning investing in forestry off-farm thereby reducing geographical risk.

7. Conclusions and Limitations of Study

7.1 Conclusions

This research has investigated the application of modern portfolio theory and the capital asset pricing model in quantitatively evaluating whether to diversify into forestry on a sheep farm. The results of the analysis indicate that forestry and agricultural price returns exhibit adequate normality to meet the model assumptions and that the model can help compare forestry returns with agricultural returns. Statistical estimation via Ordinary Least Squares regression also proved satisfactory. Other assumptions and criticisms of CAPM probably also hold about as well for forestry and agriculture as for other assets. Markets are fairly efficient, albeit not perfect, and investors are price takers. Problems with the composition of the true market portfolio, the low explanatory power of the model, and the low accuracy of prediction were exhibited in the forestry and agricultural price series, just as they have been in the financial literature. This does not invalidate the investigation of the applicability of CAPM to forestry and agricultural investments any more than it does to financial assets; it does indicate the results must be interpreted with caution.

The differences between the modern financial theory applied to forestry investment prices and the traditional forestry investment analyses should be reiterated. Traditional forestry analyses have used discounted cash flow models that begin with an initial investment in land or regeneration, determine periodic cash flows, and calculate the subsequent present values of differing investments. Such an analysis, however, does not leave one with an objective method to measure risk and the risk-return relationship among other investments. While financial analysis of financial assets also is predicated upon the expected present value of future cash flows of a company, financial analysts employ theoretical means such as the CAPM to help them discern more about risk and return. Portfolio theory goes so far as to suggest how certain assets considered for inclusion in an investor's portfolio should be chosen in order to achieve a desired risk-return level. Thus, the investment decision process can be made more objective with such methods. While these methods are unfamiliar to foresters, they are a common means of comparing different investment alternatives in the financial community. The CAPM can provide useful information on risk attributes for farm activities, which farmers can then use subjectively for farm portfolio selection and for on – farm versus off – farm diversification decisions.

The application of such financial techniques to stumpage and agricultural prices is a step towards quantifying risk and return for forestry relative to a conventional risk measure. This application can be of use to sheep farmers, or investors as a whole, who may want to invest in forestry

The results of the analyses indicate that if a farmer chooses to invest in forestry, market and total risk will be reduced and returns increased. The CAPM assumes that investors are risk averse, therefore the objective is to minimise market variance, i.e., by obtaining the least risk portfolio. It was concluded that the lowest market risk portfolio has a market risk of 0.02 percent and a return of 8 percent.

As a decision whether to diversify into forestry or not, it was concluded that diversification into forestry will reduce the risk and increase returns for the sheep farmers of New Zealand.

7.2 Limitations of Study

A number of limitations emerged from this study. These have implications for the application of the CAPM to the forestry/agricultural situation. These limitations are as follows:

1. The beta coefficients and the systematic risk coefficients were not tested to the sensitivity of whether the activity returns were deflated or not. Hence, the choice of an on – farm or off – farm diversification strategy was very much dependent on the returns including inflation. However, it could be argued that not much unexpected inflation is expected to occur over a relatively short period as with agricultural returns. On the other hand, as far as investment decisions in forestry are concerned real prices are more preferred as they are much more stable due to the length of the forest rotation (Price 1989). Lee *et al.* (1988) showed that the difference between nominal and real return is not a simple scaling problem. A simple scaling approach assumes a zero variance for the inflation rate, which

seems untenable (Lee *et al.* 1988). Therefore, it would seem prudent to conduct further research on this issue, since it could have an influence on the model results.

2. The model was applied to timber price series only; the problem of clearly quantifying the contribution of land to returns and risk still remains. Additionally, in the timber price series analysis, some regional combinations that might be expected to provide very good investment returns based on discounted cash flow basis were not among the best series as evaluated by the CAPM method.

3. This study used the returns from the New Zealand stockmarket as a proxy for the market index. It is common in the finance setting to use a country's gross domestic product (GDP) as a proxy as it is indicative of a country's overall economic performance, especially with a small country like New Zealand. However, it was very difficult to obtain *recent* published data. It would also seem advisable to conduct further research on this with a view to test whether a different index would differ significantly from those using the New Zealand stockmarket as the proxy for the market index.

4. The data used in estimating unimproved areas of the total farm area assumed that all this land was available for plantation forestry. It did not consider whether these areas were viable for forestry because of a) geography, which could

therefore make investment in forestry unprofitable due to access and harvesting constraints, or b) reserved for native forestry remnants, for example.

5. This report used a portfolio model to recommend minimum risky enterprise portfolios that estimated returns from average aggregate prices received by farmers, based on a number of farms, for the whole of New Zealand. Although, generally, aggregate yields tend to underestimate individual farm yields, the application used in this report was based on the former because of a general absence of long enough time series data on individual farms. The dangers of using aggregate yield data in farm planning are well known and theoretically demonstrated. Sheep returns based on aggregate data may reduce the variability of the returns below that which would apply in an on – farm situation.

6. These results and conclusions were obtained under conditions which apply to a specific application. Differing assumptions about geographic area, stumpage, growing stock, stumpage price, produce usage, or timber indices could produce different levels of systematic variability for timberland investments. Part of this problem is due to the lack of accurate historical market data describing timberland returns. The results of the CAPM should not be the sole criterion for accepting or rejecting an investment. The CAPM does provide a useful vehicle for capturing the return variability in the evaluation of diversification into forestry.

7. Returns for agriculture and forestry, during the period 1976 to 1987, were distorted through government intervention; therefore, not reflecting true market values. Because of this the results are unique to the measures used in this study. Activity beta coefficients reflect the systematic risk relative to the reference market portfolio, and the agricultural and forestry price series used in the CAPM. Returns were analysed for the period 1976 to 1996 as the CAPM requires a reasonable amount of data to rest on the assumption of normalcy and to also to provide a long enough time frame to allow for changes in forestry prices. It should also be noted that the schedule prices for the agricultural series used in this report were not available prior to 1976. Because of government intervention in prices, there is the question of beta stability and whether the betas obtained in this report reflect the actual betas that could be expected in the future. However, this problem is not unique to this report, as using *ex ante* data for beta calculations to predict the future is a problem faced in the wider financial community. Activity betas calculated over a different time frame could provide different beta results.

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Appendix 1

Calculation of risk adjusted rates of return for the assets lamb, mutton, wool and forestry

Year	(1) lamb schedule price[3] $/head	(2) annual lamb price change[1] (decimal)	(3) risk adjusted lamb return[6] (decimal)	(4) mutton schedule price[3] $/head	(5) annual mutton price change[1] (decimal)	(6) risk adjusted mutton return[6] (decimal)
1976	9.520			6.420		
1977	13.030	0.369	0.232	10.430	0.625	0.488
1978	11.870	-0.089	-0.199	8.510	-0.184	-0.294
1979	14.060	0.184	0.037	9.400	0.105	-0.042
1980	15.190	0.080	-0.063	11.860	0.262	0.118
1981	15.390	0.013	-0.139	10.270	-0.134	-0.287
1982	20.670	0.343	0.173	9.940	-0.032	-0.202
1983	20.810	0.007	-0.124	10.460	0.052	-0.079
1984	22.640	0.088	-0.062	12.120	0.159	0.008
1985	24.210	0.069	-0.164	14.860	0.226	-0.007
1986	12.740	-0.474	-0.665	5.440	-0.634	-0.825
1987	19.060	0.496	0.285	8.820	0.621	0.410
1988	16.340	-0.143	-0.297	12.480	0.415	0.261
1989	19.780	0.211	0.075	9.000	-0.279	-0.414
1990	30.600	0.547	0.408	18.000	1.000	0.861
1991	26.040	-0.149	-0.249	11.690	-0.351	-0.450
1992	27.970	0.074	0.007	12.420	0.062	-0.005
1993	40.160	0.436	0.373	25.760	1.074	1.011
1994	39.970	-0.005	-0.072	26.730	0.038	-0.030
1995	32.170	-0.195	-0.285	21.700	-0.188	-0.278
1996	36.540	0.136	0.041	24.220	0.116	0.021

Year	(7) wool schedule price[3] c/kg clean	(8) annual wool price change[1] (decimal)	(9) risk adjusted wool return[6] (decimal)	(10) stumpage price Canterbury returns[4] ($/m^3)	(11) annual stumpage price change[1] (decimal)	(12) risk adjusted stumpage return[6] (decimal)
1976	215.800			29.500		
1977	299.800	0.389	0.252	30.500	0.034	-0.103
1978	262.300	-0.125	-0.235	32.000	0.049	-0.061
1979	298.900	0.140	-0.008	34.000	0.063	-0.085
1980	358.200	0.198	0.055	35.000	0.029	-0.114
1981	377.200	0.053	-0.100	36.000	0.029	-0.124
1982	345.500	-0.084	-0.254	42.000	0.167	-0.003
1983	346.700	0.003	-0.127	40.000	-0.048	-0.178
1984	397.700	0.147	-0.003	48.000	0.200	0.050
1985	507.900	0.277	0.044	54.000	0.125	-0.108
1986	463.300	-0.088	-0.279	63.000	0.167	-0.024
1987	556.200	0.201	-0.011	57.500	-0.087	-0.298
1988	603.600	0.085	-0.069	54.000	-0.061	-0.215
1989	614.500	0.018	-0.117	53.000	-0.019	-0.154
1990	422.800	-0.312	-0.451	51.500	-0.028	-0.167
1991	437.100	0.034	-0.066	56.000	0.087	-0.012
1992	432.800	-0.010	-0.077	63.000	0.125	0.058
1993	413.800	-0.044	-0.107	85.000	0.349	0.286
1994	553.800	0.338	0.271	79.000	-0.071	-0.138
1995	494.400	-0.107	-0.197	80.000	0.013	-0.077
1996	443.100	-0.104	-0.199	78.868	-0.014	-0.109

Year	(13) annual market price[5]	(14) annual market price change[1] (decimal)	(15) risk adjusted market return (decimal)	(16) risk free interest rate[2] (decimal)
1976	312.973			
1977	290.873	-0.071	-0.208	0.137
1978	318.738	0.096	-0.014	0.110
1979	342.412	0.074	-0.073	0.147
1980	446.268	0.303	0.16	0.144
1981	638.374	0.430	0.278	0.153
1982	626.055	-0.019	-0.189	0.170
1983	893.688	0.427	0.297	0.131
1984	1322.268	0.480	0.329	0.150
1985	1608.688	0.217	-0.016	0.233
1986	2831.192	0.760	0.569	0.191
1987	3048.479	0.077	-0.134	0.211
1988	1930.283	-0.367	-0.521	0.154
1989	2034.000	0.054	-0.082	0.135
1990	1612.568	-0.207	-0.346	0.139
1991	1432.914	-0.072	-0.172	0.100
1992	1483.480	0.059	-0.008	0.067
1993	1811.684	0.294	0.231	0.063
1994	2092.934	0.228	0.160	0.067
1995	2074.908	0.057	-0.033	0.090
1996	2192.478	0.132	0.037	0.095

1. $(price_n - price_{n-1})/price_n$ from columns 1,4,7,10,13
2. 90-day Treasury bill rate, from New Zealand Treasury
3. From New Zealand Meat and Wool Boards' Economic Service
4. From the Ministry of Forestry
5. From the New Zealand Stock Exchange
6. Price change from columns 1,4,7,10,13 - column 16

Appendix 2

Risk-return portfolio weights for forestry and agricultural investment portfolios. Average portfolio expected return (%) and standard deviation (%) are also presented

Asset		Portfolio weights (%)										
lamb		40	38	36	34	32	30	28	26	24	22	20
mutton		30	28.5	27	25.5	24	22.5	21	19.5	18	16.5	15
wool		30	28.5	27	25.5	24	22.5	21	19.5	18	16.5	15
forestry		0	5	10	15	20	25	30	35	40	45	50
expected return (%)	$\overline{R}$	5.81	5.98	6.15	6.32	6.49	6.66	6.82	6.99	7.16	7.33	7.50
market risk	$\beta_p^2\sigma_m^2$	8.33	7.69	7.04	6.40	5.76	5.12	4.47	3.83	3.19	2.55	1.90
non-market risk	$\sigma_{\varepsilon p}^2$	13.98	13.74	13.52	13.33	13.17	13.05	12.96	12.93	12.94	13.02	13.15
total risk	σ_p^2	22.31	21.42	20.56	19.73	18.93	18.16	17.44	16.76	16.13	15.56	15.06

Asset		Portfolio weights (%)									
lamb		18	16	14	12	10	8	6	4	2	0
mutton		13.5	12	10.5	9	7.5	6	4.5	3	1.5	0
wool		13.5	12	10.5	9	7.5	6	4.5	3	1.5	0
forestry		55	60	65	70	75	80	85	90	95	100
expected return (%)	$\overline{R}$	7.67	7.84	8.01	8.18	8.34	8.513	8.68	8.85	9.02	9.19
market risk	$\beta_p^2\sigma_m^2$	1.26	0.62	0.02	0.67	1.31	1.95	2.59	3.24	3.88	4.52
non-market risk	$\sigma_{\varepsilon p}^2$	13.36	13.65	13.97	13.15	12.42	11.78	11.23	10.78	10.41	10.13
total risk	σ_p^2	14.63	14.27	14.00	13.82	13.73	13.73	13.83	14.02	14.29	14.65

Appendix 3

New Zealand Meat and Wool Board's Economic Service sheep farm survey - 1994-95 average farm area.

Production region	Effective grazeable area	Agro-forestry area	Total effective area (ha)	Forestry area	Unimproved area	Total farm area
North-South Auckland	296		296	5	48	349
East Coast North Is.	478		478	10	56	544
Taranaki-Manawatu	380	1	381	10	34	425
North Island	379	1	380	8	48	436
Marlb.-Canterbury	744	1	745	7	34	786
Otago-Southland	745	1	746	3	19	768
South Island	742	1	743	5	29	777
New Zealand	559	1	560	6	39	605

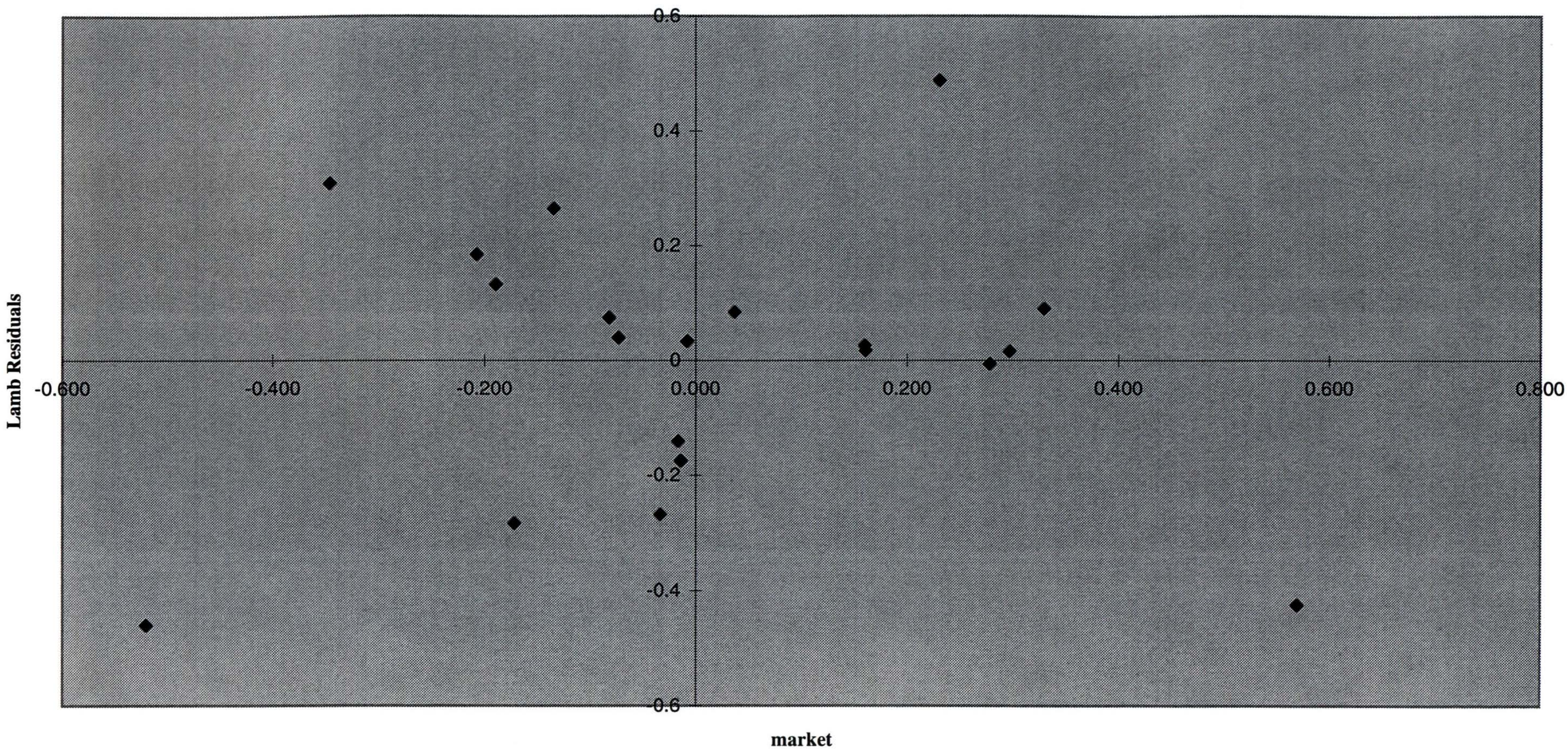
Production region	percentage of farms in sheep	forestry	areas not being utilised
North-South Auckland	84.8	1.4	13.8
East Coast North Is.	87.9	1.8	10.3
Taranaki-Manawatu	89.6	2.4	8.0
North Island	87.2	1.8	11.0
Marlb.-Canterbury	94.8	0.9	4.3
Otago-Southland	97.1	0.4	2.5
South Island	95.6	0.6	3.7
New Zealand	92.6	1.0	6.4

Production region	Total area avaialble for forestry (%) (incl. areas already in forestry)
North-South Auckland	15.19
East Coast North Is.	12.13
Taranaki-Manawatu	10.35
North Island	12.84
Marlb.-Canterbury	5.22
Otago-Southland	2.86
South Island	4.38
New Zealand	7.44

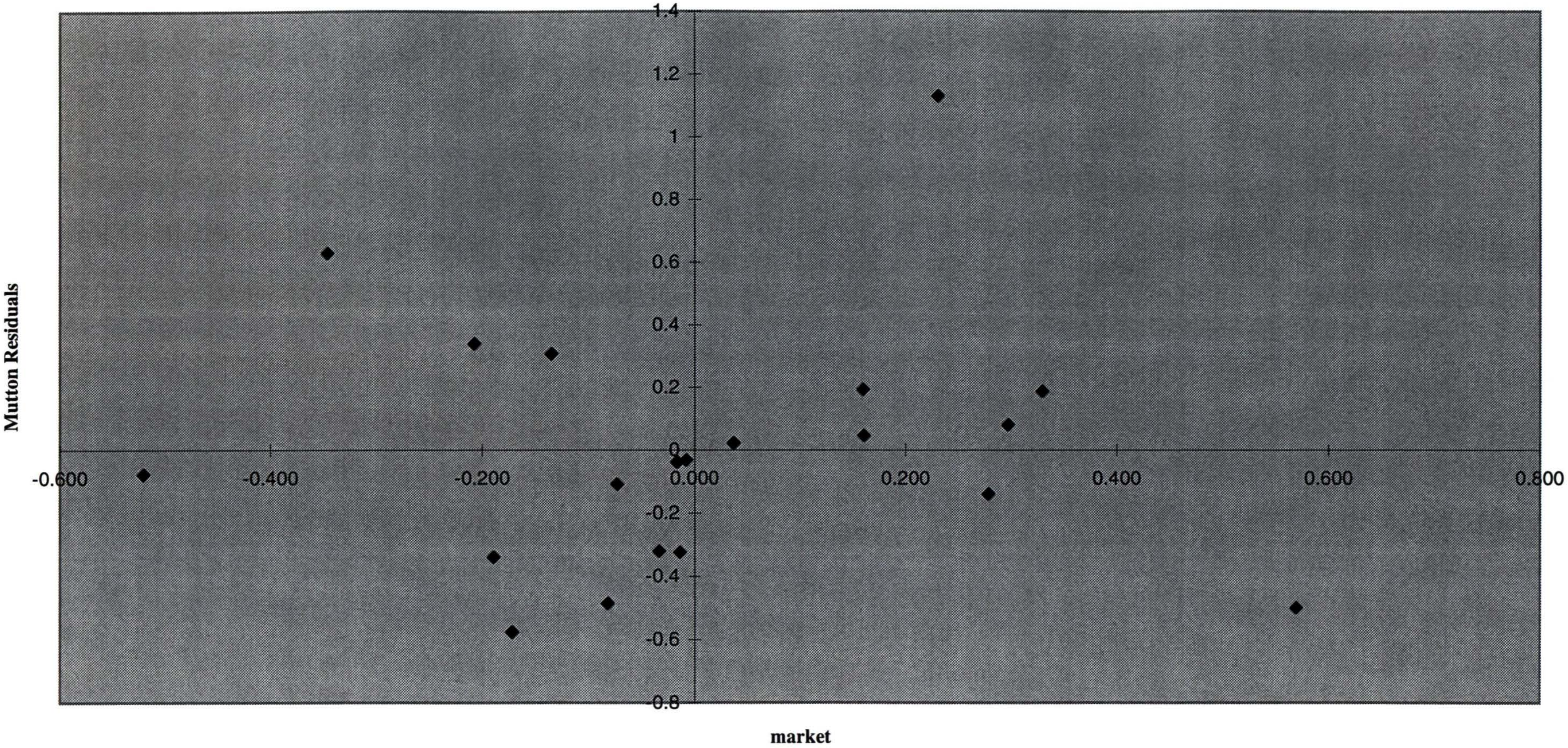
Production region	percentage of income derived from each agricultural asset as a percentage of total farm area for each region			
	lamb	mutton	wool	forestry
all farming	40	30	30	0
all forestry	0	0	0	100
North-South Auckland	33.93	25.44	25.44	15.19
East Coast North Is.	35.15	26.36	26.36	12.13
Taranaki-Manawatu	35.86	26.89	26.89	10.35
North Island	34.86	26.15	26.15	12.84
Marlb.-Canterbury	37.91	28.44	28.44	5.22
Otago-Southland	38.85	29.14	29.14	2.86
South Island	38.25	28.69	28.69	4.38
New Zealand	37.02	27.77	27.77	7.44

Appendix 4

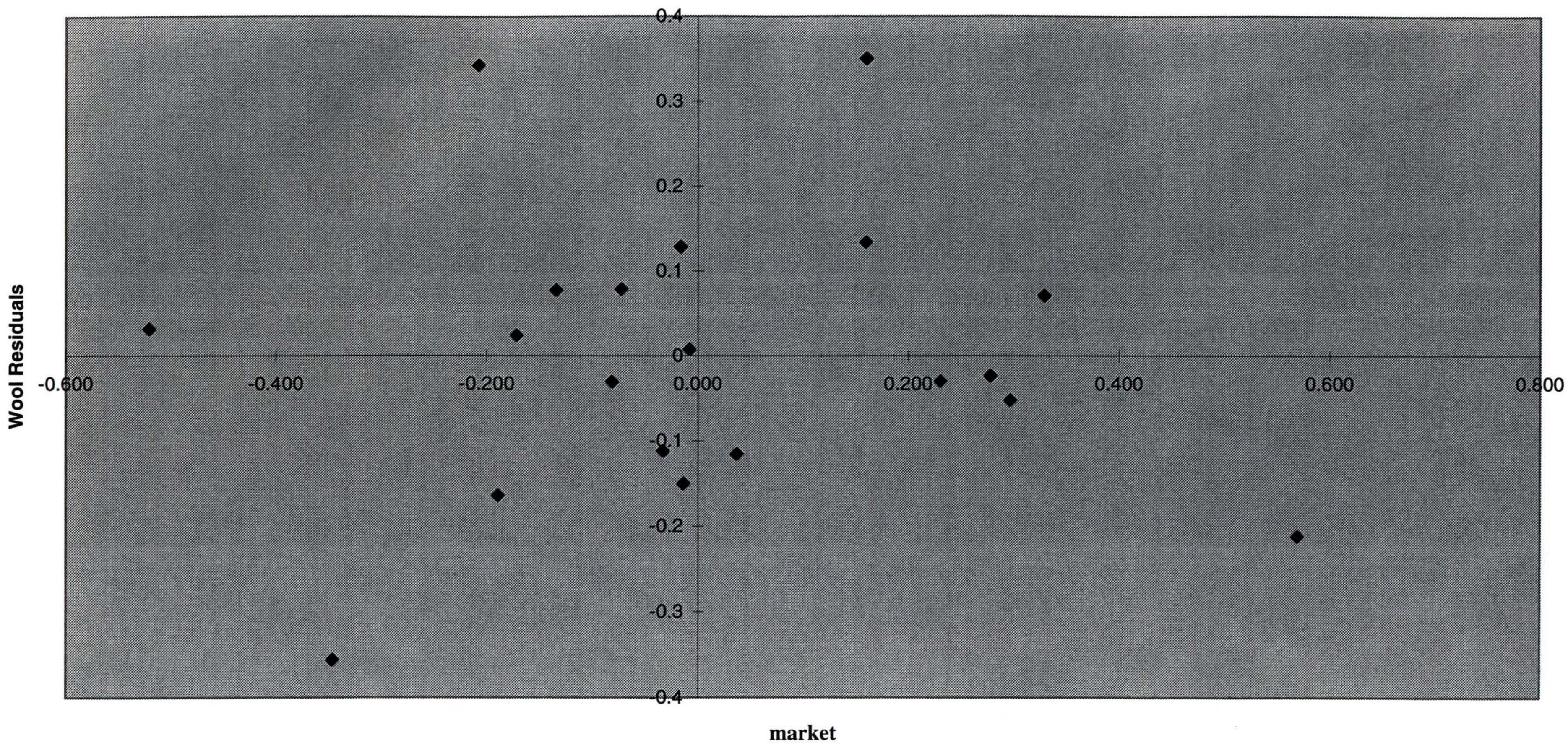
market Residual Plot



market Residual Plot



market Residual Plot



market Residual Plot